Preface

BCI2000 is a system of four modules that are independently executable programs. They are described in detail in two documents: outline.pdf and specific.pdf. An overview of their organization can be seen in Figure P.1.

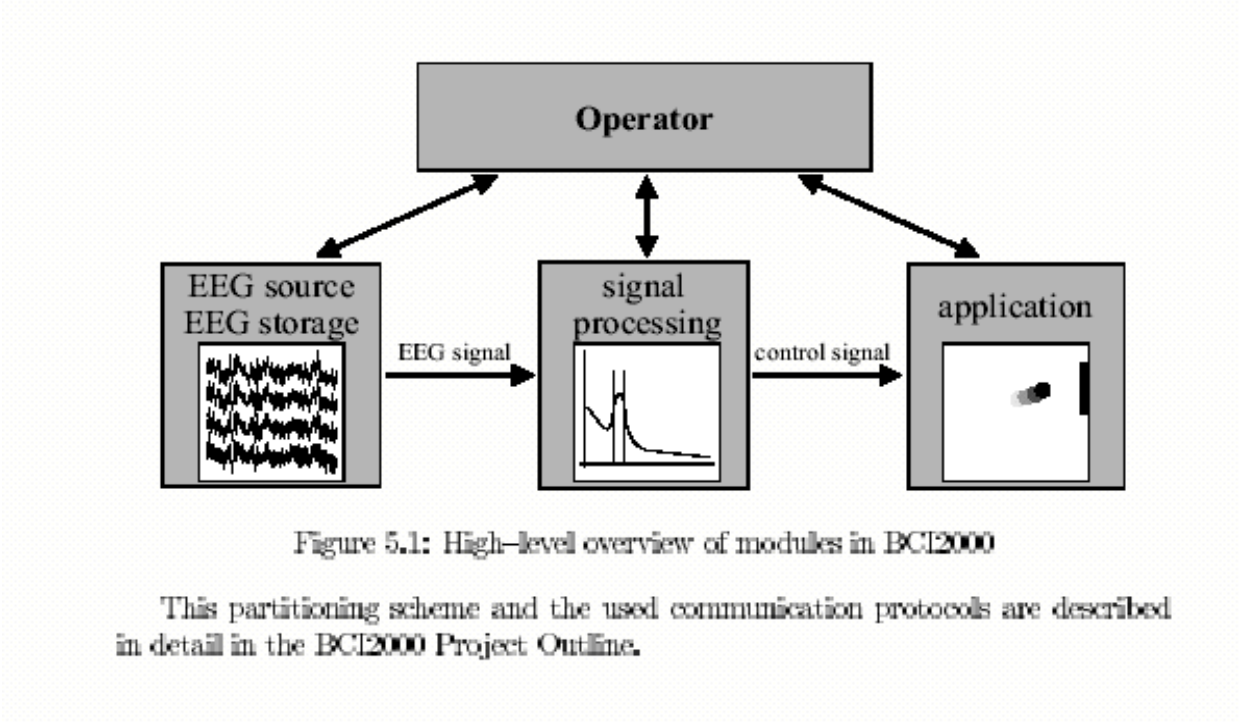


Figure P.1. Overview of the four BCI2000 modules.

The EEG source module acquires EEG data from the A/D convertor, stores it to disk, and passes a sub-set of the EEG signal to the signal processing module. The signal processing performs a series of cascaded filtering operations that result in a cursor-control signal that is passed to the application module. The application module controls the users' task and the appearance of the users' screen. The operator module serves as a interface between the human operator and the BCI2000 system by collecting parameters and displaying data.

The four modules of BCI2000 can be associated with a series of menus used to input the parameters of the system. BCI2000 can be configured with various combinations of Source, Signal Processing, and Application modules. For example, for mu rhythm training the configuration could include the ARSignalProcessing module and the D2Box Application. The menus associated with this configuration are illustrated below in Figure P.2.

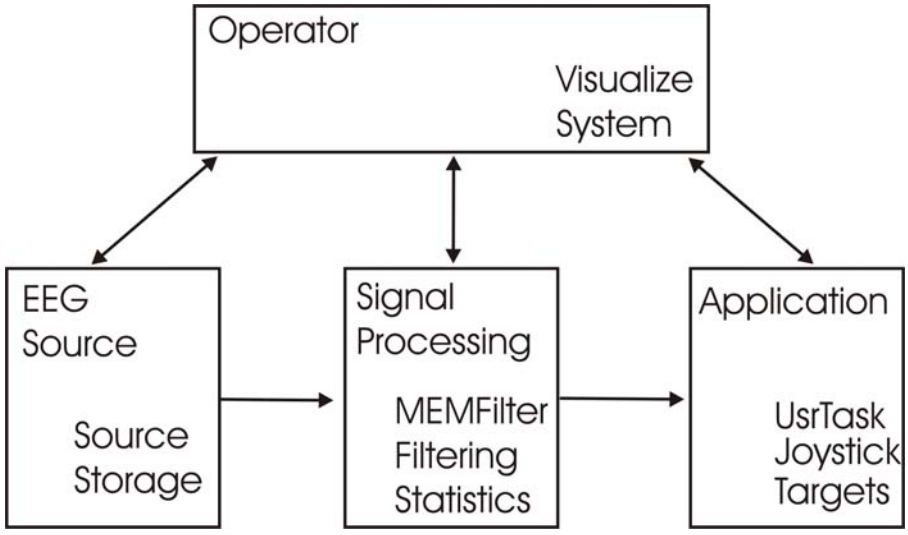


Figure P.2- Association between the four modules and the various configuration menus.

The Source menu and the storage menu originate in the EEG source module and are concerned with its' operation. The signal processing module produces the MEMFiltering, filtering and statistics menus. The application is configured by the UsrTask, Joystick and Targets menu. Finally the operator uses the Visualize and System menus. While the visualize menu actually originates in the three other modules it is concerned with the operators' data display function.

In order to work properly, the BCI2000 system must have values set for the parameters found in these menus. The system starts with default values. Changes may be made manually be the operator or by reading in parameter files. Parameter files may be read in as complete lists of all parameters or as parameter file fragments that modify only a subset of the parameters.

BCI2000 can also be configured for P3 spelling. In the case the P3SignalProcessing and P3Speller application can be used. The menus associated with this configuration are shown in Figure P.3.

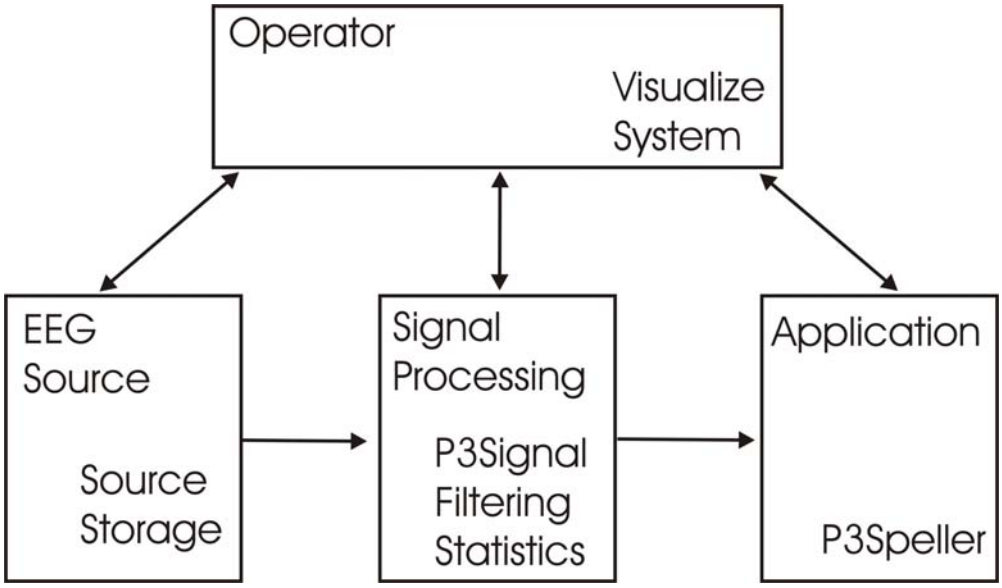


Figure P.3- Association of the four P3 modules and the various configuration menus.

Notice that several of the menus are common to the two applications. The signal processing module now has a P3DignalProcessing menu in place of the MEMFilter menu and the application has a P3Speller menu in place of UsrTask, Joystick and Targets.

Chapter 1- Basic Operation

BCI2000 Consists of four separate programs that run simultaneously. These are the operator, data acquisition, signal processing, and the user application. All four programs must be started and connected for the system to work. They may be started individually, in which case they will appear as seen in Figure 1 below.

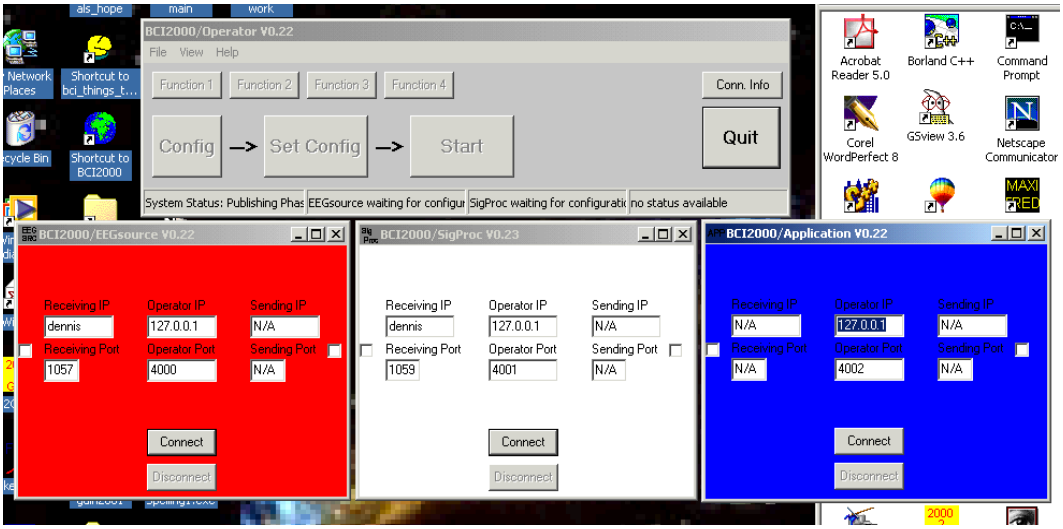


Figure 1. Screen appearance of the four programs launched manually.

In order to connect the programs click on the 3 **Connect** buttons.

Alternatively, the four programs may be launched from a batch file, in which case all programs except the operator may be invisible, as seen in Figure 2.

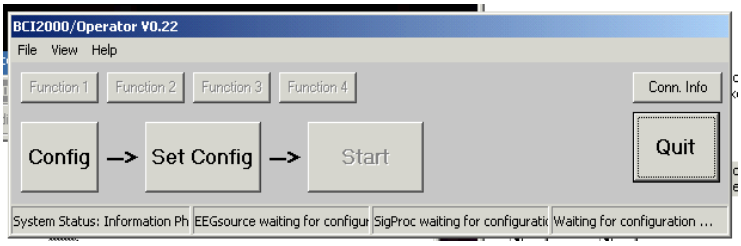


Figure 2. Screen appearance of the operator program.

BCI2000 has many parameters that need to be entered for proper operation. In order to do so click on the **Config** button. The configuration menus will then appear.

One appearance of the configuration menu is shown in Figure 3. It is important to note that the appearance of these menus is dynamic in the sense that they depend upon the features included in the current version of BCI2000.

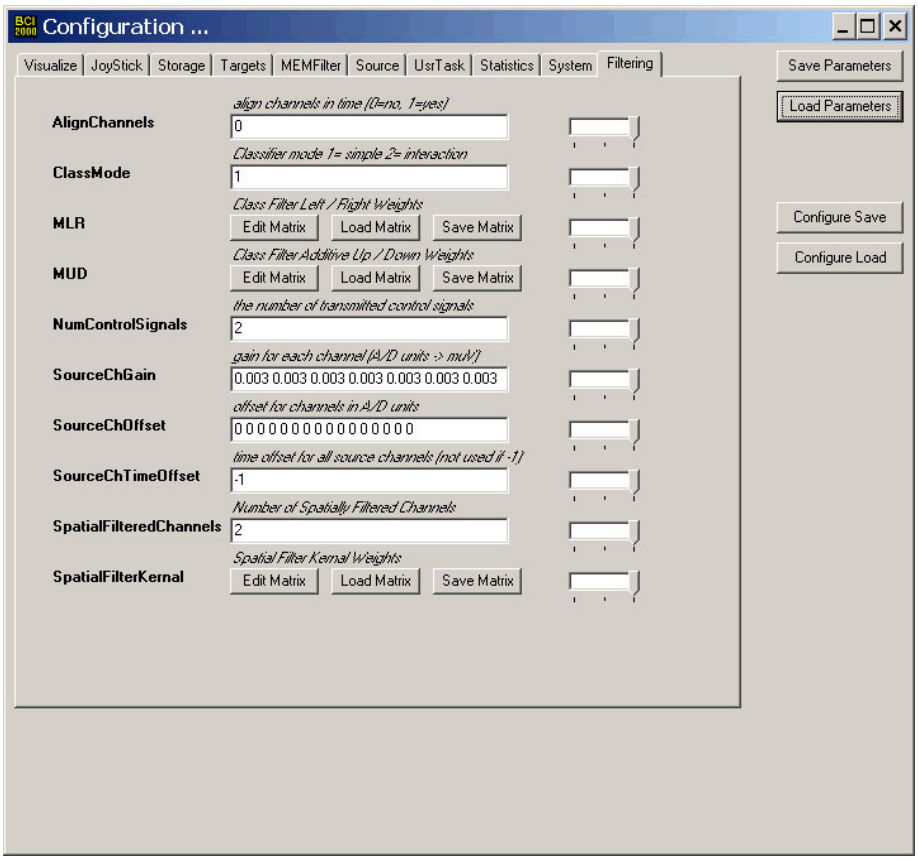


Figure 3. Appearance of the configuration menu.

Note the tabs at the top of the menu. The particular menu shown is that associated with the storage tab. There are 10 menu tabs shown in Figure 3. These are:

Visualize- controls the data shown to the human operator during operation.
Joystick- configures possible use of joystick input
Storage- parameters that control naming of data files.
Targets- configures number, size, and positioning of targets
MEMFilter- parameters of AR spectral analysis.
Source- parameters of data acquisition.
UsrTask- parameters of the subjects' task.
Statistics- parameters that control automatic adaptive adjustments.
System- parameters that control communication between the four programs.
Filtering- parameters that control signal processing.

Each of these menus can be selected by clicking on the corresponding tab. Also note that the menu shown in Figure 3 shows four additional buttons on the right hand side. These are:

Save Parameters- stores parameters in a file.
Load Parameters- inputs parameters from a file.
Configure Save- provides selection of parameters that will not be saved to parameter file.
Configure Load- provides selection of parameters that will not be read from parameter file.

If the system has been parameterized and the results has been saved in a file, system operation is relatively simple. Just click on the **Load Parameter** button and the menu shown in Figure 4 will appear.

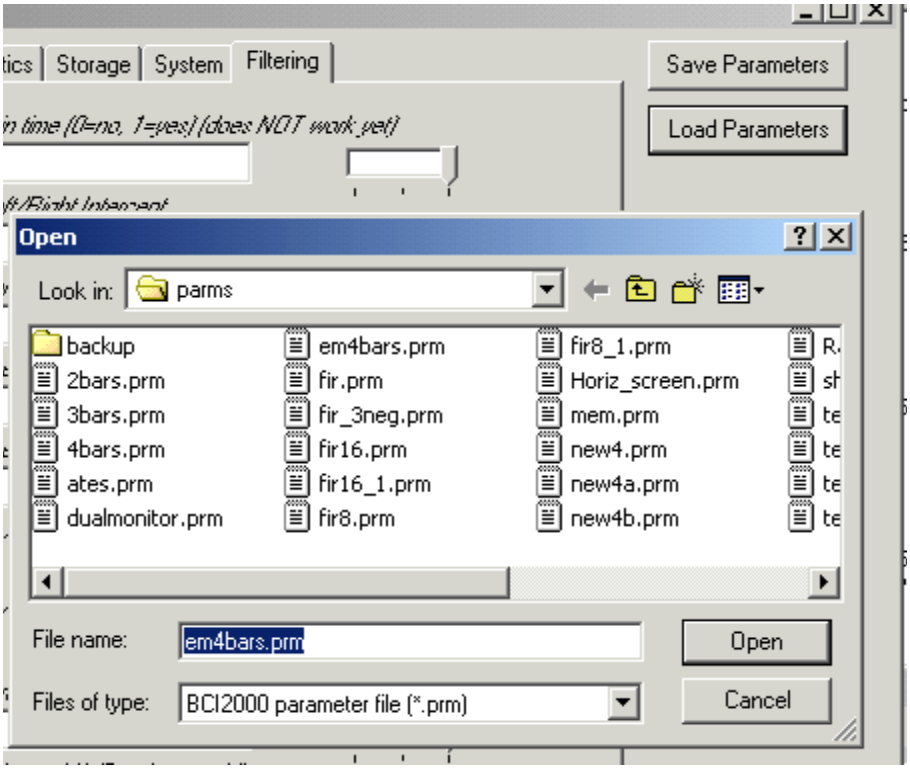


Figure 4. The Load Parameter menu.

The file containing the preselected parameters can then be loaded. Then parameterization of BCI2000 is completed by adding the storage parameters.

Click on the storage tab and the Storage menu (Figure 5) will appear. This contains the following parameters:

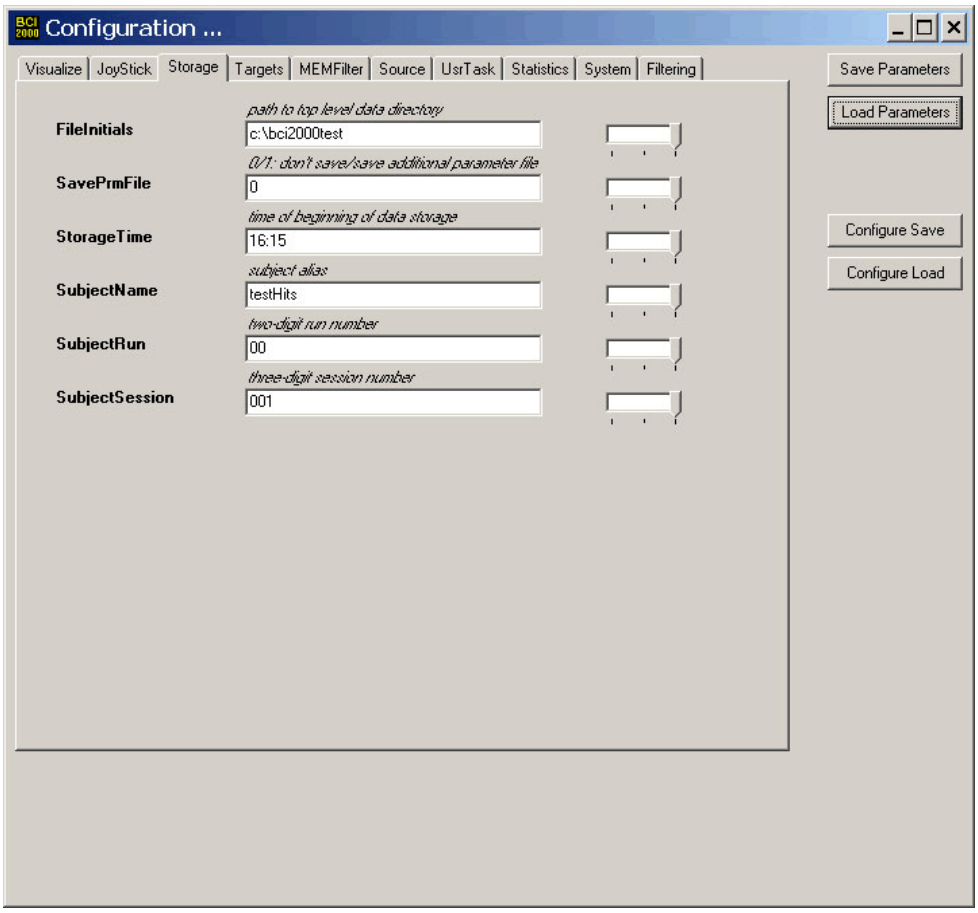


Figure 5- Appearance of the storage menu.

AutoIncrementRunNo- controls whether or not run number automatically advances.
FileInitials- the disk and directory where the data files will be stored.
SavePrmFile- controls whether or not the parameter file used for each run is saved.
StorageTime- time when data file is created.
SubjectName- initials identifying the subject.
SubjectRun- number of the current run.
SubjectSession- number of the current session.

When al of these parameters have proper values the Configuration menu can be closed (click on **X** in upper hand corner). Next click on the **Set Configuration** button and the operator program will appear as in Figure 6.

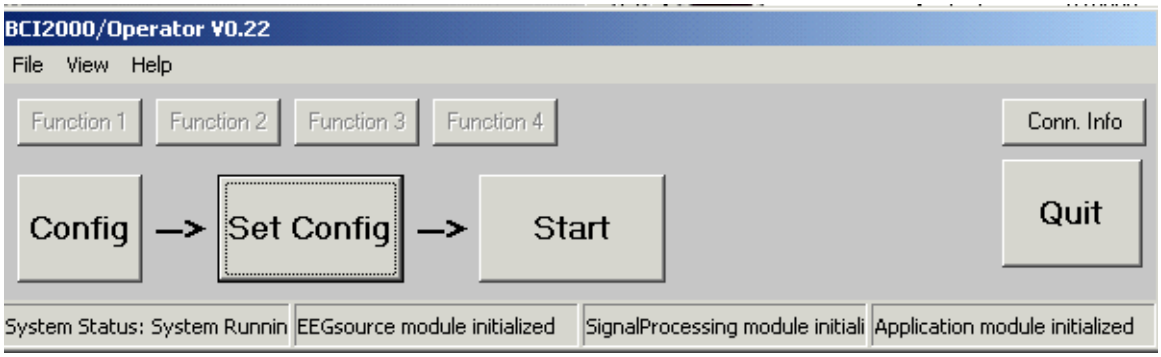


Figure 6. Appearance of operator program after configuration.

Notice that the **Start** button has become bold. This happens only after clicking **Set Configuration**. The system is ready and the session will begin when you click on **Start**.

When the system starts several displays will appear. The particular data displays that are present will depend upon the parameters selected from the Visualize menu. One configuration is shown in Figure 6.

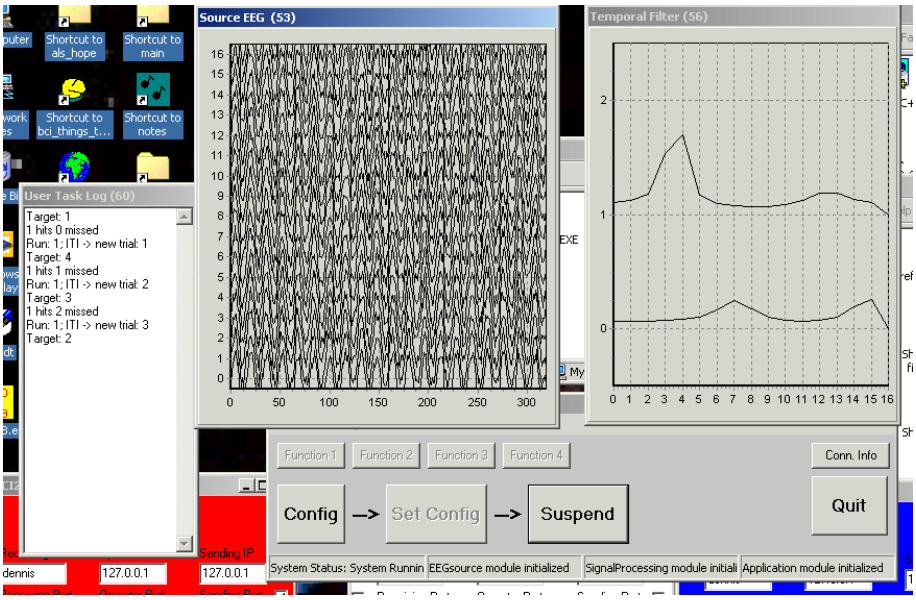


Figure 7. Appearance of BCI2000 during operation.

Figure 7 shows a configuration in which the parameters **VisualizeSource** and **VisualizeTemporalFilter** have been selected. Also note that the **Start** button has changed to a **Suspend** button. Clicking on the **Suspend** button will halt operation.

If you are creating a new parameter file, several of the Configuration menus will need to be dealt with. There are two ways of doing this. One way is to enter all parameters by hand. Another way is to partially configure the system by using parameter file fragments. For example, the menu shown in Figure 4 lists several parameter files such as **4bars.prm** and **dualmonitor.prm. 4bars.prm** contains only those parameters necessary to configure the system for a 4 target task**. dualmonitor.prm** contains only those parameters necessary to place the users monitor on the second video screen. These two parameter file fragments can be read in succession. Since they are fragments, only those parameters that they include will be changed. Thus, some of the work of configuring the system can be done with a series of standard parameter file fragments.

Configuring BCI2000

The first step in configuring BCI2000 involves selection of the data acquisition parameters. The Source menu is shown in Figure 8 as it appears when using the DT3000.exe module.

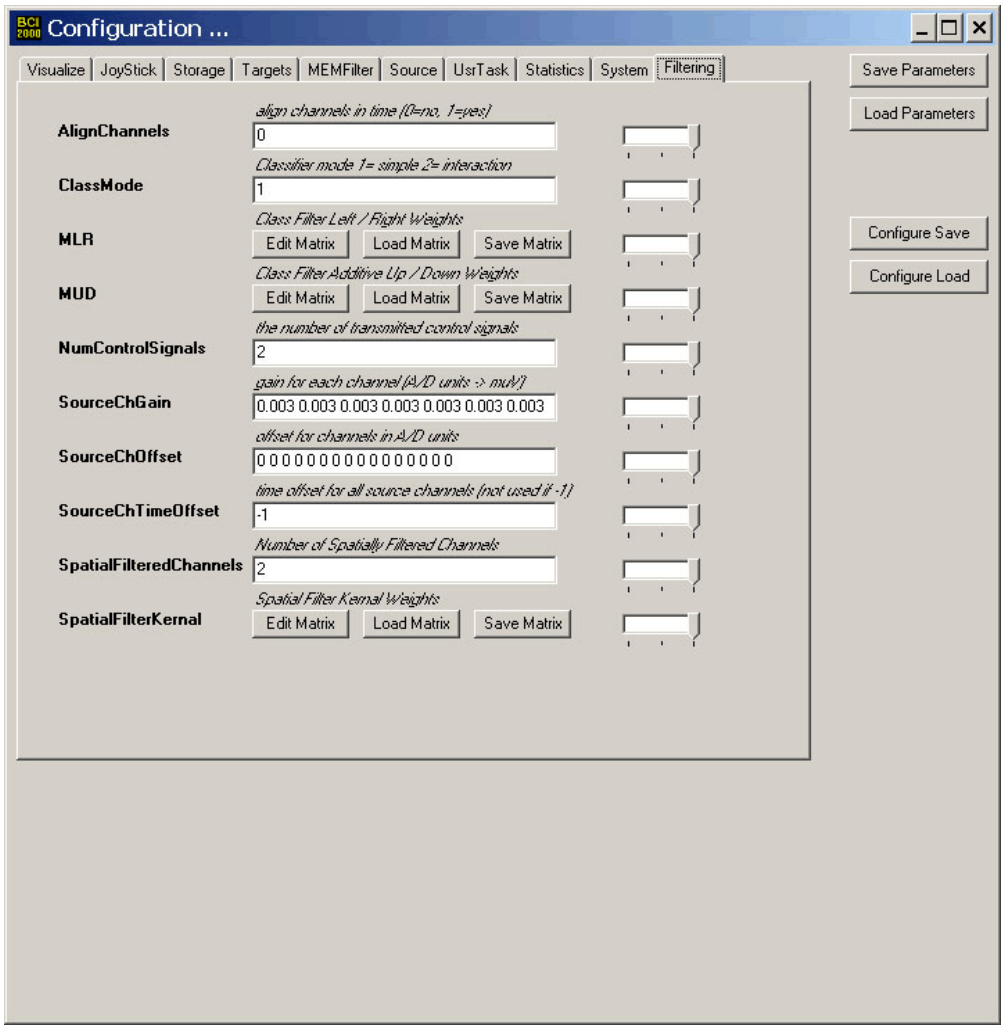


Figure 8. Appearance of the source menu.

The source menu contains the following parameters:

BoardName- the name of the Data Translation board as it appears in the driver information.

BoardName2- the name of a second (optional) Data Translation board

SampleBlockSize- size of data (per channel) block for each cycle of operation.

SamplingRate- data acquisition rate in Hz.
SoftwareCh- number of channels sampled (and stored) by the data acquisition program.
SoftwareChBoard1- number of channels from first board (ignored when only 1 board.
SoftwareChBoard2- number of channels from second board (ignored when 1 board)
TransmitCh- number of channels transmitted to signal processing.
TransmitChList- identity of channels transmitted to signal processing.

In the example shown in Figure 8, a sample block size of 32 and a sampling rate of 256 result in the system running at 8 cycles/sec. This means that data is processed every 1/8th of a second and that the cursor will move 8 times/sec. All 64 channels of data are recorded and stored. However only 4 of these channels are passed to signal processing.

The parameters of the spectral analysis are entered in the **MEMFilter** menu, which is shown in Figure 8.

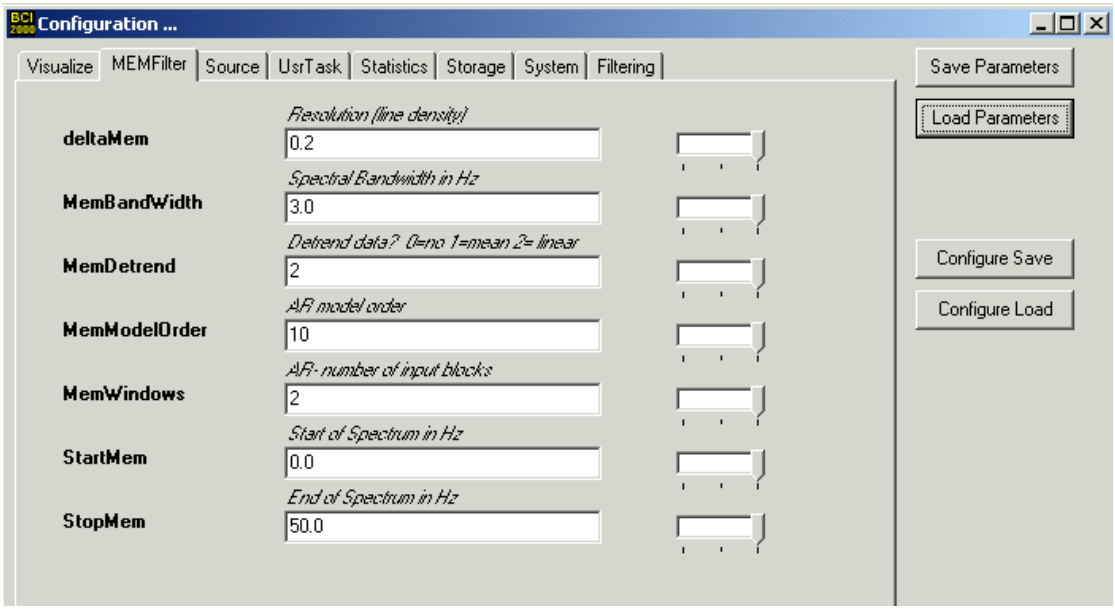


Figure 9. Appearance of the MEMFilter menu.

These values could be entered by the mem.prm parameter fragment that can be seen in Figure 4. The **MEMFilter** parameters are:

deltaMem- specifies the resolution (in Hz) with which the autoregressive model is evaluated.

MemBandWidth- specifies the width (in Hz) of the spectral bands produced.

MemDetrend- whether or not linear detrending is preformed.

MemModelOrder- the order of the AR model.

MemWindows- the number of data blocks (each SampleBlockSize long) used per spectrum.

StartMem- beginning point at which the spectrum is evaluated.

StopMem- ending point at which spectrum is evaluated.

In the example shown, a 10^{th} order AR model is evaluated from 0 to 50 Hz in 3 Hz bands. Each 3 Hz band consists of the average of the (15) points evaluated at 0.2 Hz intervals. The linear trend in the data is removed prior to fitting the AR model.

The parameters of the other parts of signal processing are accessed in the **Filtering** menu. The appearance of the Filtering menu is shown in Figure 10.

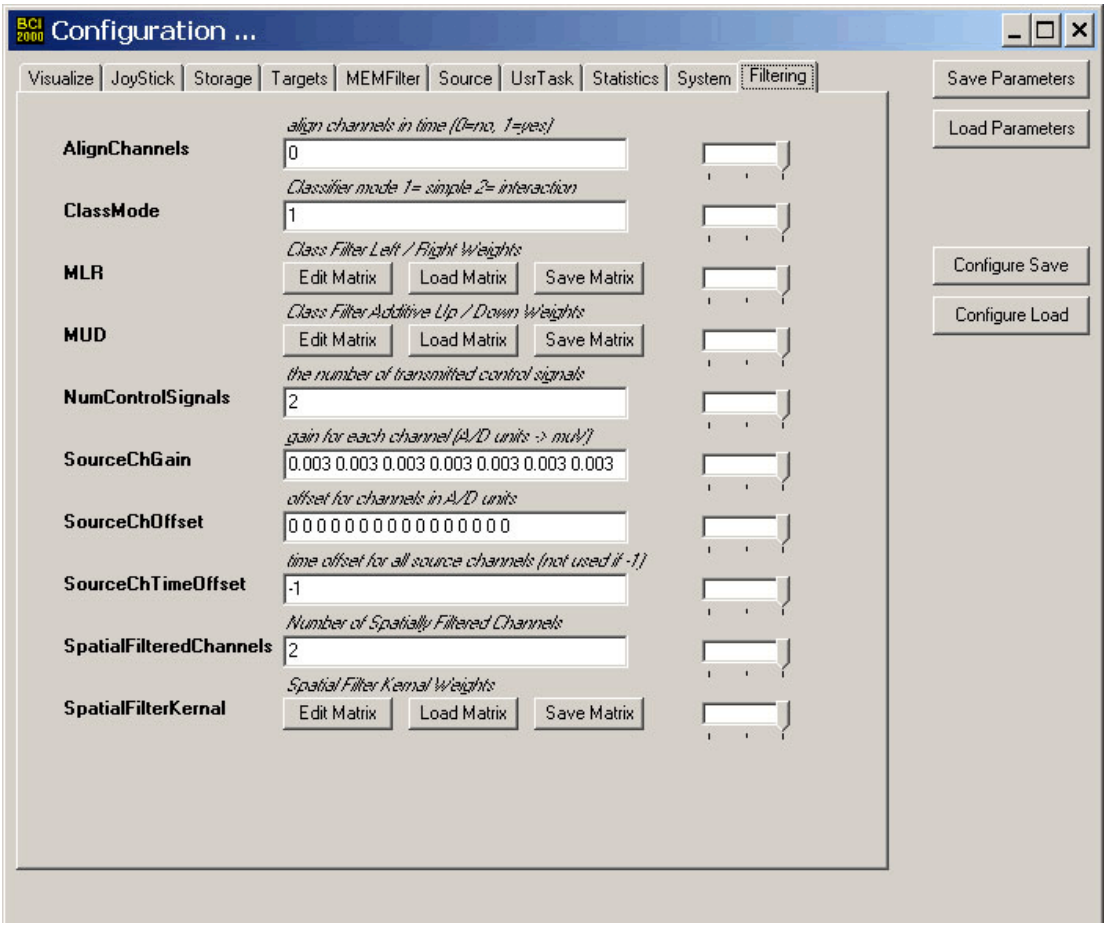


Figure 10. Appearance of the Filtering menu.

The filtering menu has the following parameters:

AlignChannels- whether or not a linear interpolation is used to align channels in time

ClassMode- the classifier can operate in a simple mode (mode 1) or in a mode allowing interaction terms (mode 2).

MLR- matrix that defines the channels and frequencies that determine horizontal movement

MUD- matrix that defines the channels and frequencies that determine vertical movement

NumControlSignals- number of control signals (up/down and right/left)

SourceChGain- list of gain values for each channel to convert A/D units to microVolts

SourceChOffset- list of intercept values to convert A/D units to microVolts

SpatialFilteredChannels- Number of spatial filter output channels
SpatialFilterKernal- Matrix that defines spatial filter transformation

There are several parameters (e.g., MUD,. SpatialFilteKernal) that have Edit Matrix and Load Matrix options. The use of the Edit Matrix with the **SpatialFilterKernal** option is illustrated in Figure 11. The vallues of the spatial filtering matrix can also be read in from a file with the **Load Matrix** option.

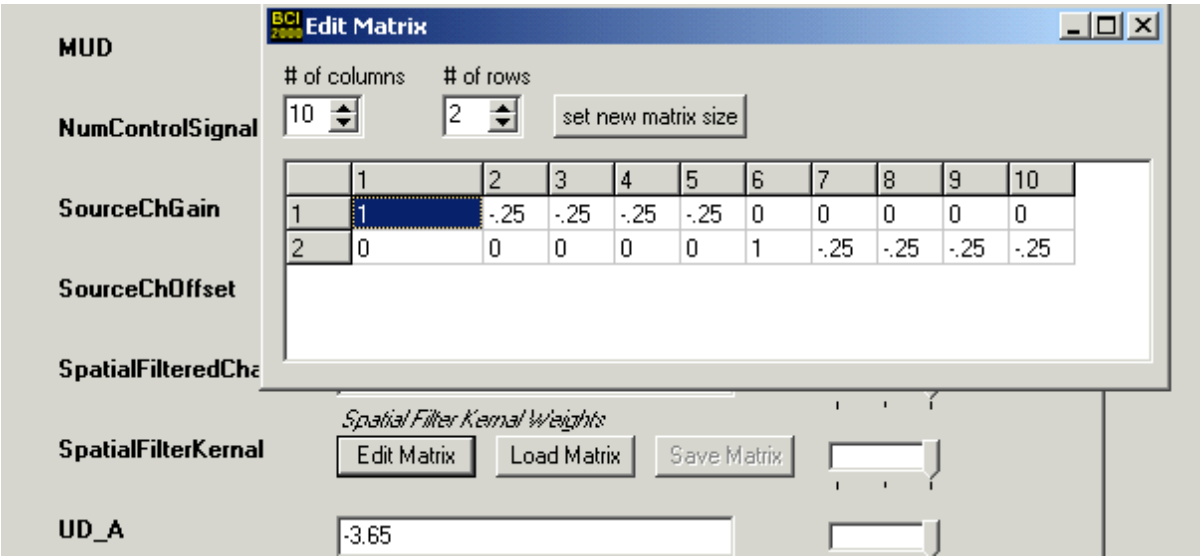


Figure 11. The Edit Matrix option for the SpatialFilterKernal.

Notice that there are 10 columns and 2 rows in this example. The rows and columns can be set by the **set new matrix size** button that appears in the top center of the menu. The 10 columns correspond to the 10 **TransmitCh** values of the **source** menu. That is, in the example shown previously in Figure 7, the source menu specified that 10 channels are sent to signal processing. These correspond to the columns of the spatial filtering matrix. In the current example, the parameter **SpatialFilteredChannels** is 2. This corresponds to the rows of the spatial filtering matrix and corresponds to the number of channels that are the output of the spatial filtering operation. This will then be the number of channels input to spectral analysis (**MEMFilter**) and the class filters (**MUD** and **MLR**). Thus, there is an interdependence between some of the parameters. In this example, **TransmitCh** (from the source menu) corresponds to the columns of the spatial filter matrix (from the Filtering menu) as well as the number of elements in **SourceChGain** and **SourceChOffset (**also from the Filtering menu).

The Edit Matrix option from the horizontal class filter (**MUD**) is illustrated in Figure 12 (note that MUD stands for **M**atrix **U**p **D**own).

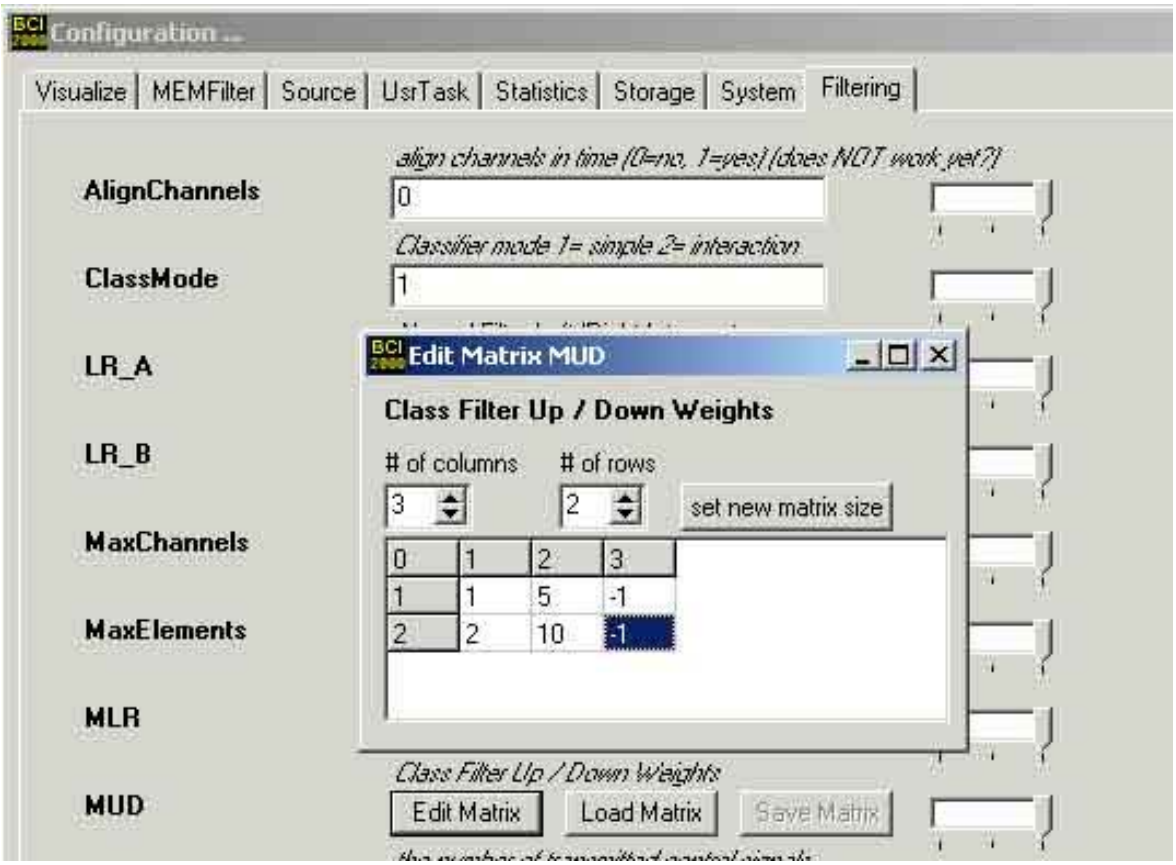


Figure 12. Edit Matrix for MUD when ClassMode = 1.

In the example shown in Figure 12, there are 2 rows and 3 columns. When the **variable ClassMode is = 1** then 3 columns are required. The 2 rows correspond to two input features from the spectral analysis. The 3 columns contain information that selects the features and weights associated with these features. Column 1 specifies the **SpatialFilteredChannel** and column 2 specifies the spectral bin associated with the first component of the feature. Column 3 specifies the **SpatialFilteredChannel**. Column 3 specifies the weight of the feature. The control signal for vertical movement would then be the weighted sum of the feature specified in

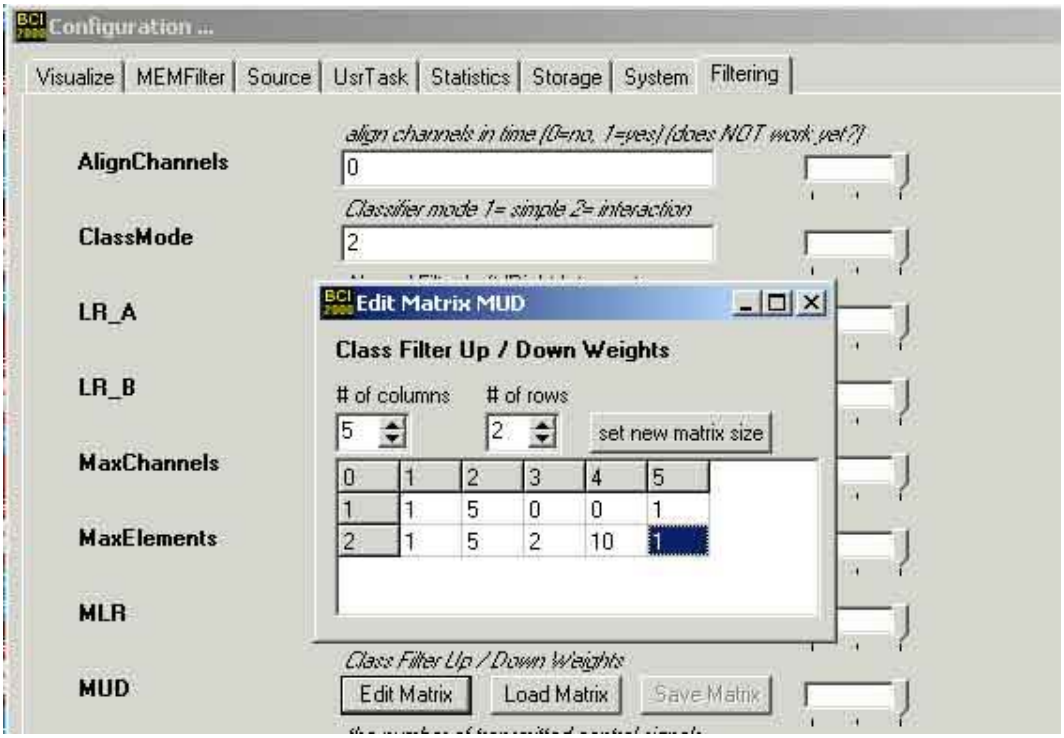


Figure 12b. Edit Matrix option when ClassMode= 2.

In the example shown in Figure 12b, ClassMode= 2 has been entered and 2 rows and 5 columns appear. This indicates that the product of two features will be computed for each row. When 0 appears in columns 3 and 4 only one feature is used for that row. When non-zero indices specify a second component (columns 3 and 4) this is multiplied by the first component (column 1 and 2). This provides a means of generating interaction terms (products). This example illustrates another interdependence in the system. The **MUD** matrix must match the **SpatialFilterKernal** in the sense that there must be **SpatialFilteredChannels** and spectral bins corresponding to the features specified in **MUD**. A full list of system dependencies will be presented in Table 1.1 below.

The S**tatistics** menu provides for input of parameters that control automatic adaptation of the system and is shown in Figure 13.

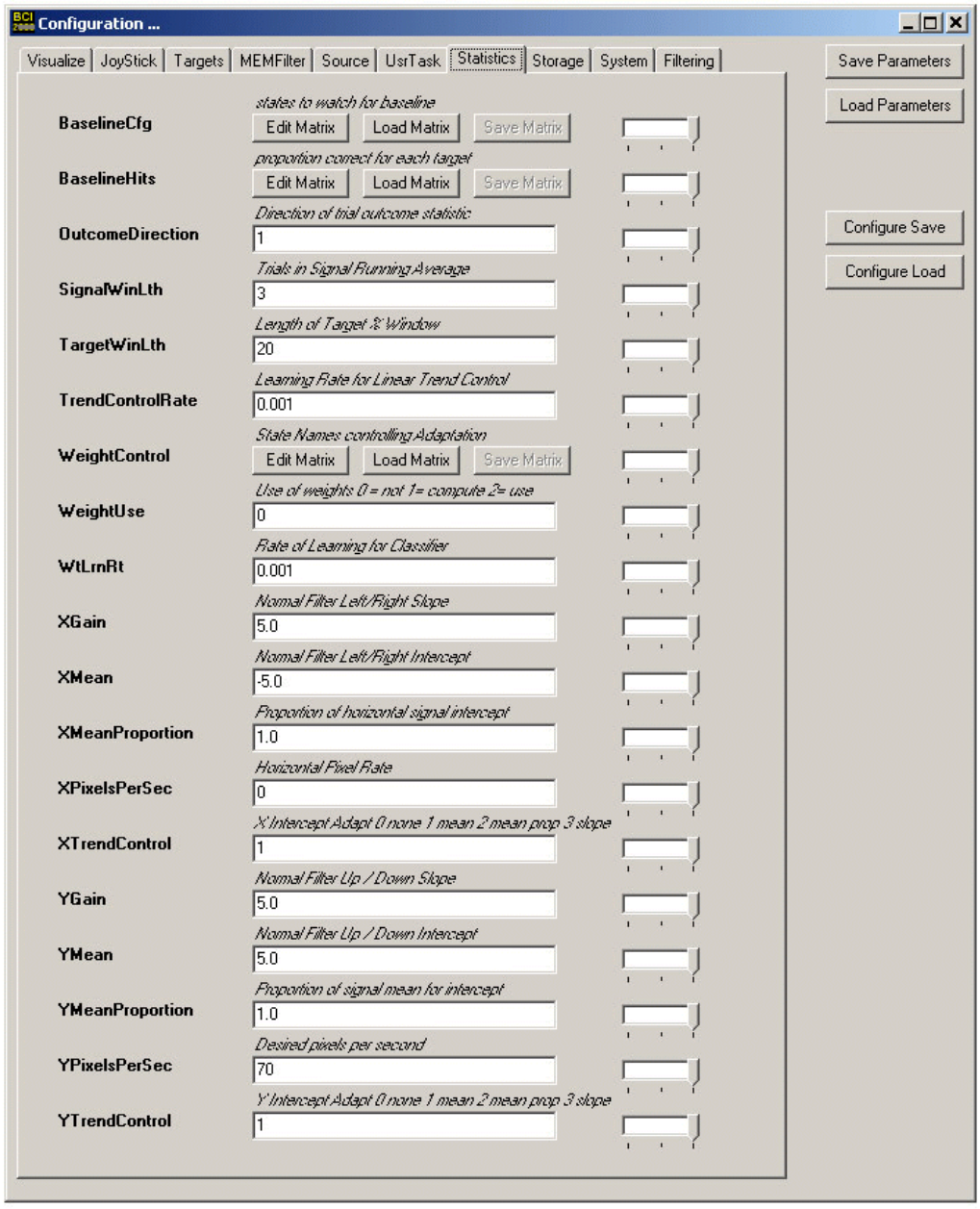


Figure 13. Appearance of the statistics menu.

The statistics parameters are:

BaselineClg- matrix for selection of baseline used for cursor gain and intercept control.
BaselineHits- matrix of a running average of the proportion correct for each target.

OutcomeDirection- Direction of trial outcome statistic: 1 for positive (e.g. proportion correct) and 2 for negative (e.g. latency to hit target)

SignalWinLth- number of trials per target in running average of signal statistics

TargetWinLth- number of trials per target in running average of trial statistics

TrendControlRate- learning rate for Trend Control Algorithm

WeightControl- matrix of state names used for adaptation

WeightUse- controls use of online adaptation of classifier weights. 0 for no use, 1 for compute but do not use and 2 for use on-line

WtLrnRt- learning rate for Weight control algorithm

XGain- Value of the slope for horizontal movement

XMean- Value of the intercept for horizontal movement

XMeanProportion- proportion of the mean of the X control signal used as the intercept.

XPixelsPerSec- rate of horizontal cursor movement in pixels per second.

XTrendControl- trend control adaptation. 0= none, 1= remove mean from control signal, 2= adjust mean by a proportion to remove linear trend, 3= gain adjustment to remove quadratic trend

YGain- Value of the slope for vertical movement

YMean- Value of the intercept for vertical movement

YMeanProportion- proportion of the mean of the Y control signal used as the intercept.

YPixelsPerSec- rate of vertical cursor movement in pixels per second.

YTrendControl- trend control adaptation. 0= none, 1= remove mean from control signal, 2= adjust mean by a proportion to remove linear trend, 3= gain adjustment to remove quadratic trend

The Edit Matrix option for **BaselineClg** is shown in Figure 15.

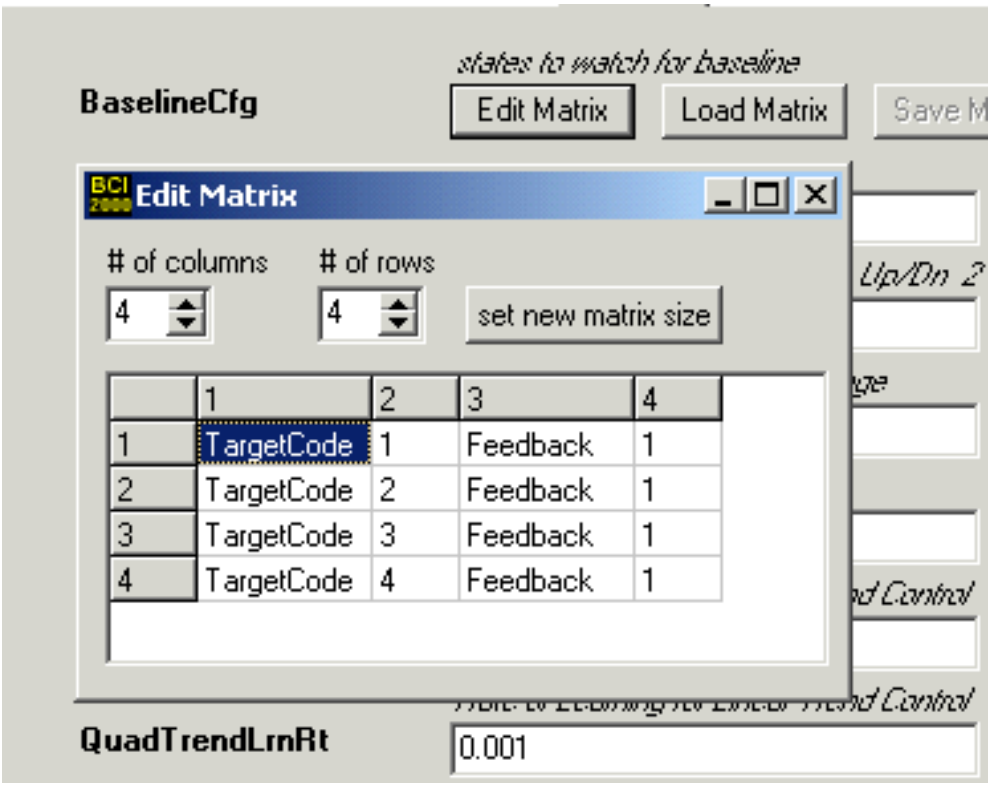


Figure 15. The Edit Matrix option of **BaselineClg**..

In the example shown there are 4 rows and 4 columns. The example is for a task with 4 targets (see **UsrTask** below). The data used for adaptation of cursor movement parameters will be taken from the four **TargetCode** values shown when the value of **Feedback** is 1.

The Edit Matrix option for **BaselineHits** is shown in Figure 16.

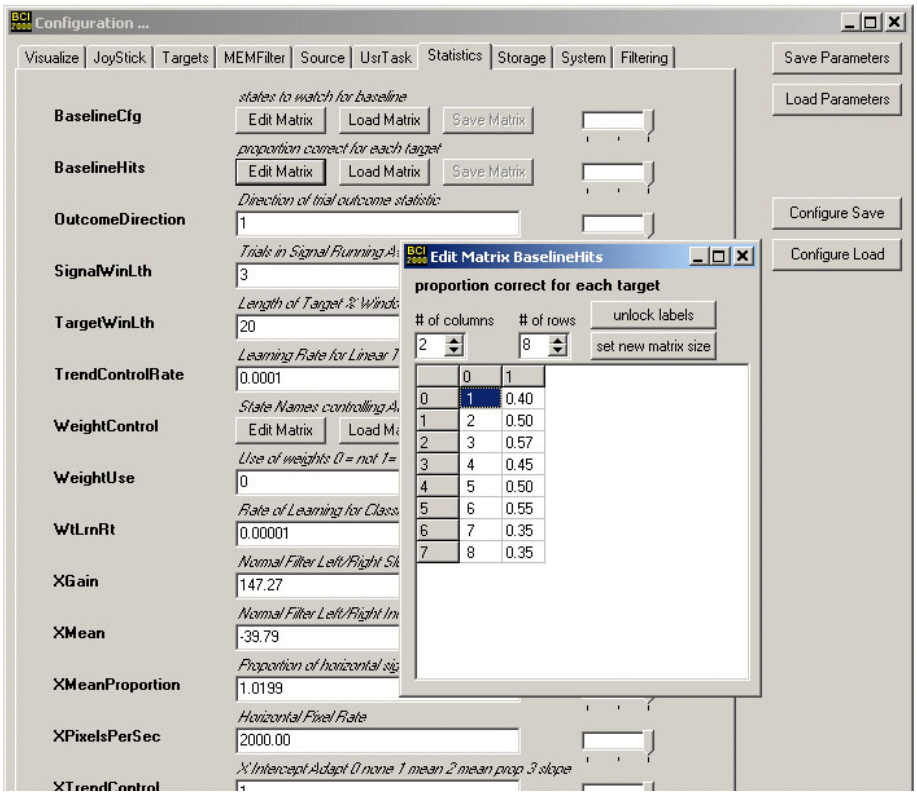


Figure 16. The BaselineHits menu

The example shown has 12 rows for each of twelve targets. This information is used by the adaptive trend control algorithm.

The Edit Matrix option for WeightControl is shown in Figure 17

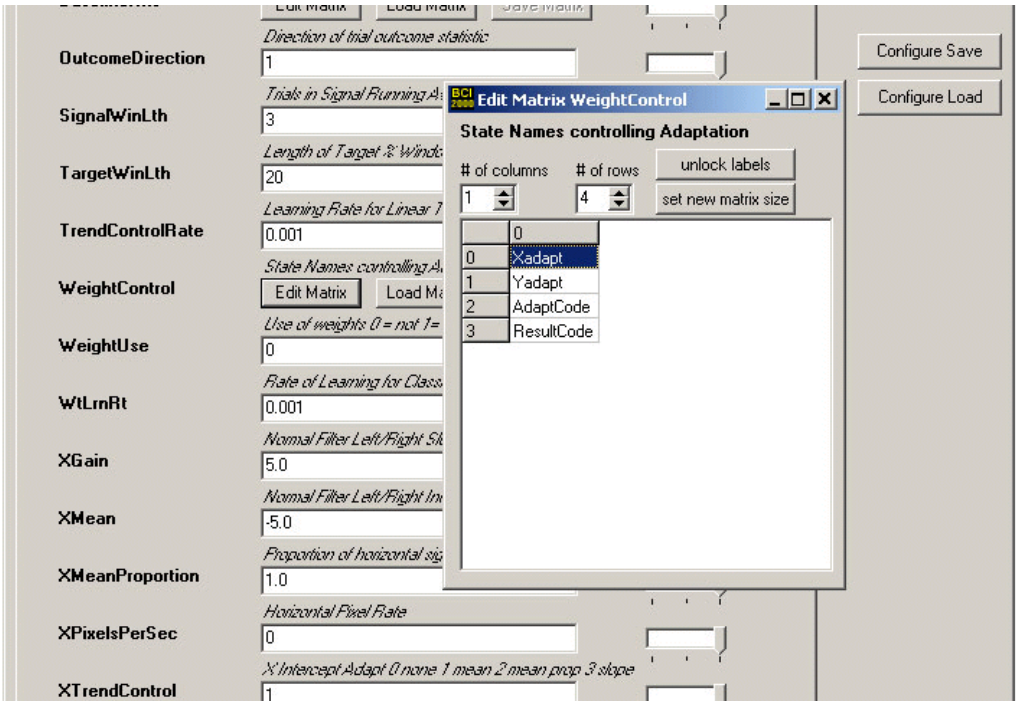


Figure 17. The WeightControl menu

The example lists 4 state names that are used by the statistics module for adaptive control. These are states that originate in the Application module. There values are used in the statistics part of the Signalprocessing module.

The UsrTask menu provides for input of the parameters that control the users' task and is shown in Figure 18.

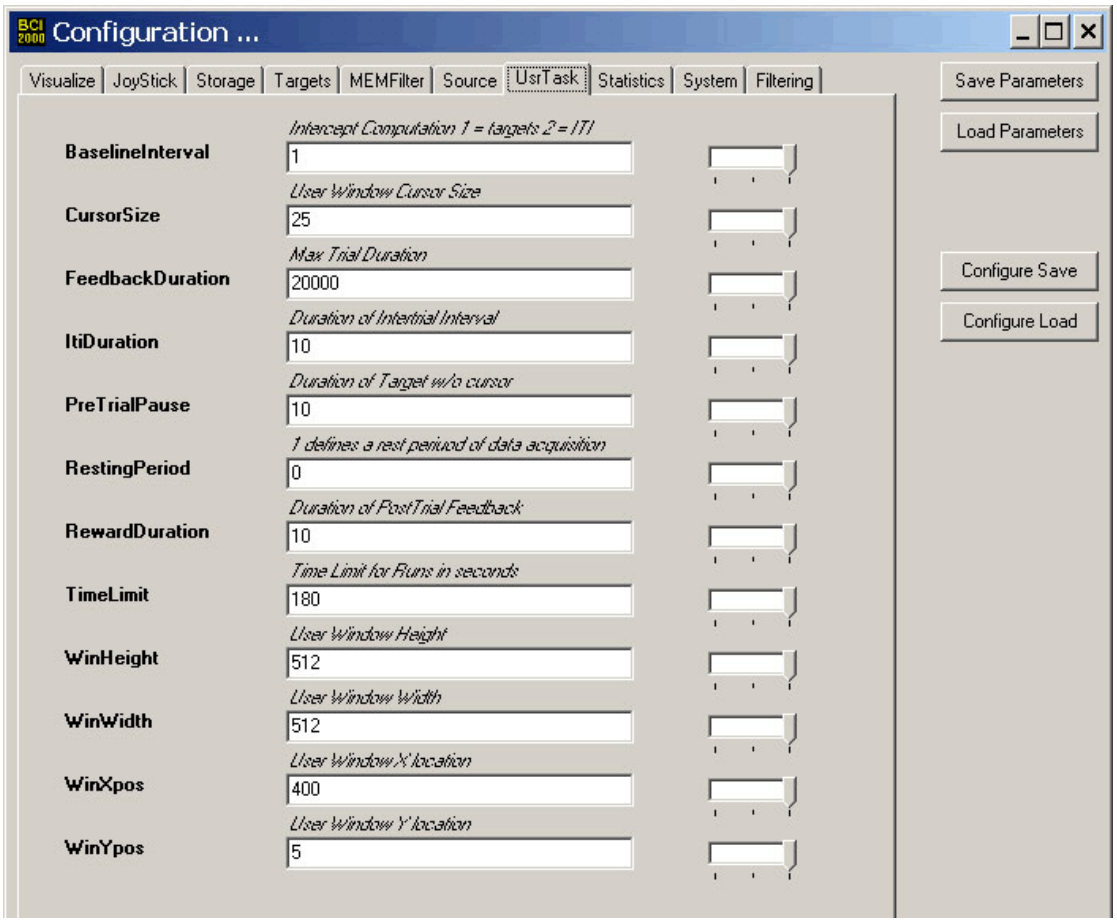


Figure 18. Appearance of the UsrTask menu.

The UsrTask menu has the following parameters:

BaseLineInterval- Intercept computation: 1 for targets, 2 for ITI
CursorSize- the size of the cursor in pixels (pixel size depends on screen settings).
FeedbackDuration- max trial length in cursor steps
ITIDuration- the duration of the period between trials (in units of cursor updates).
PreTrialPause- the duraion of initial target appearance without cursor present
RestingPeriod- mode where baseline is taken (rather than target presentations).
RewardDuration- duration that trial outcome is displayed (in cursor update units).

TimeLimit- Duration of run in secs.
WinHeight- height of user window in pixels
WinWidth- width of user window in pixels.
WinXpos- horizontal position of upper left user window (in pixels).
WinYpos- vertical position of upper left user window (in pixels).

The appearance of the users' screen is shown in Figure 19.

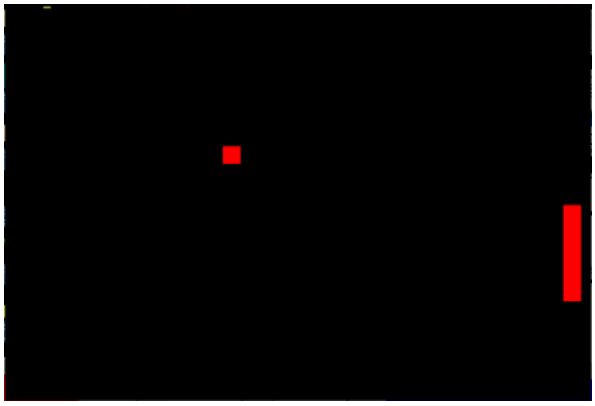


Figure 19 Appearance of Users' screen. Note the cursor and the target.

The Targets Menu is shown in Figure 20.

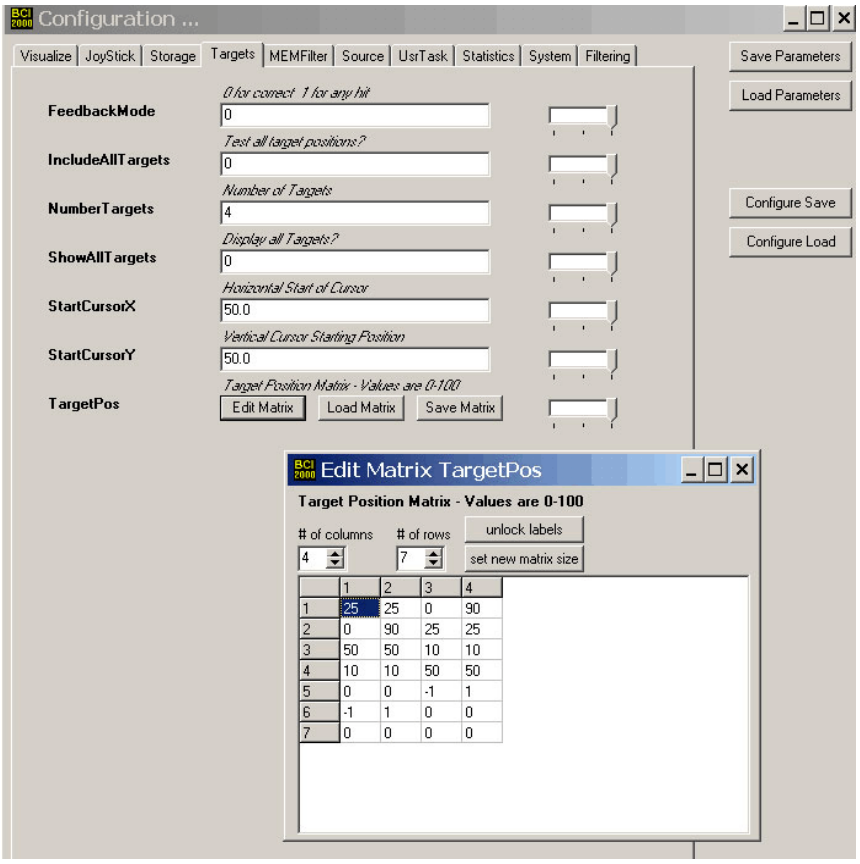


Figure 20. The Targets Menu

The Targets menu has the following parameters:

FeedbackMode- if 0 only correct target flashes, if 1 any target flashes when hit

IncludeAllTargets: If 0 is selected the trial continues until the correct target is hit or the trial times out. If 1 is selected the trial terminates when any target (visible or not) is hit.

NumberTargets: the number of targets to be displayed

ShowAllTargets: 0 for correct target only, 1 for all targets displayed

StartCursorX: the horizontal starting position of the cursor in percent of total screen area.

StartCursorY: the vertical starting position of the cursor in percent of total screen area.

TargetPos: a matrix of Target position values and other information

Figure 20 also shows the Edit Matrix menu for TargetPos. The example shows 8 columns and 7 rows. The 8 columns correspond to the values for each of the 8 targets. The 7 rows correspond

to the 7 distinct values associated with each target. Row 0 contains the X (horizontal) starting position in percent of total screen area for each target. Row 1 contains the Y (vertical) starting position in percent of total screen area. Row 2 contains the X width of each target. Row 3 contains the Y height of each target. Row 4 contains a zero-mean value that describes the relative X location of each target. This value is used by several adaptive algorithms. Row 5 contains a zero-mean value that describes the relative Y location of each target. Row 6 contains a value that controls adaptation of the control signal weights for each target. A value of 0 results in no adaptation. A value of 1 allows adaptation on the X dimension. A value of 2 allows adaptation on the Y dimension. A value of 3 allows adaptation on both dimensions.

The **Visualize** menu provides for entering parameters that control the run-time display of data and is shown in Figure 21.

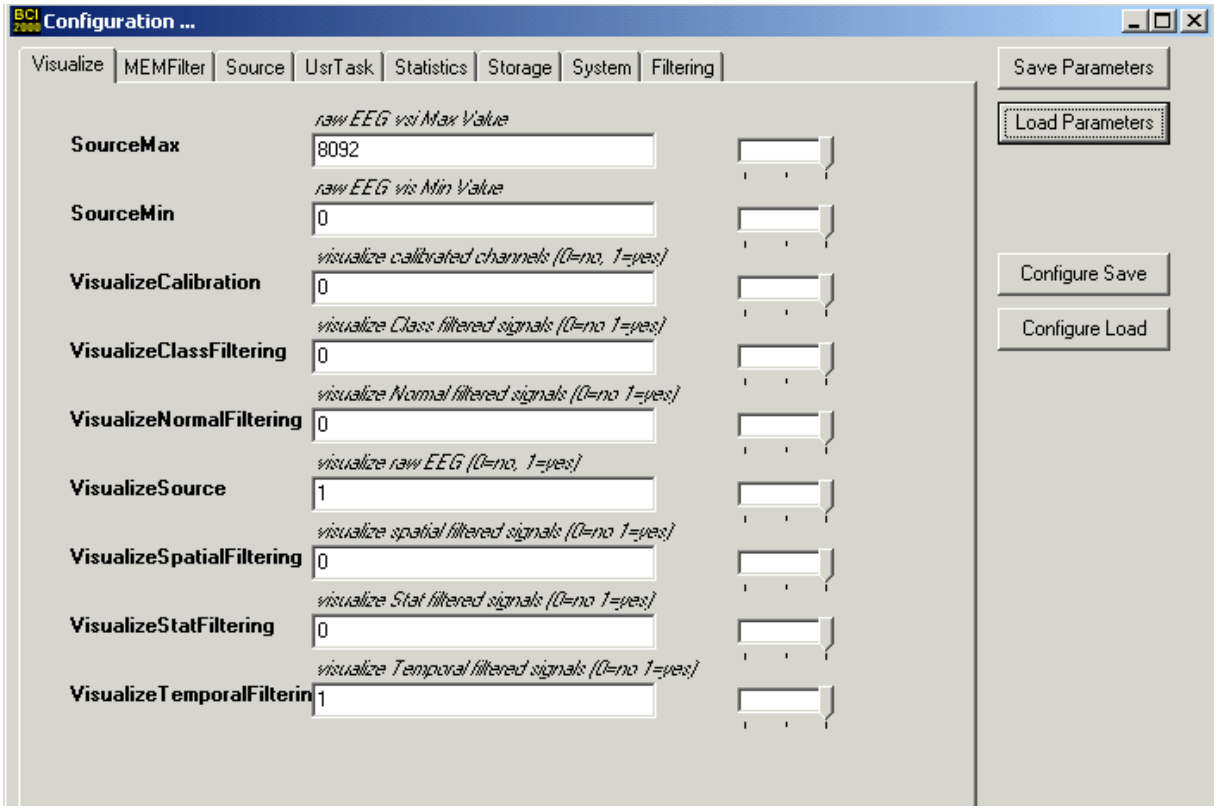


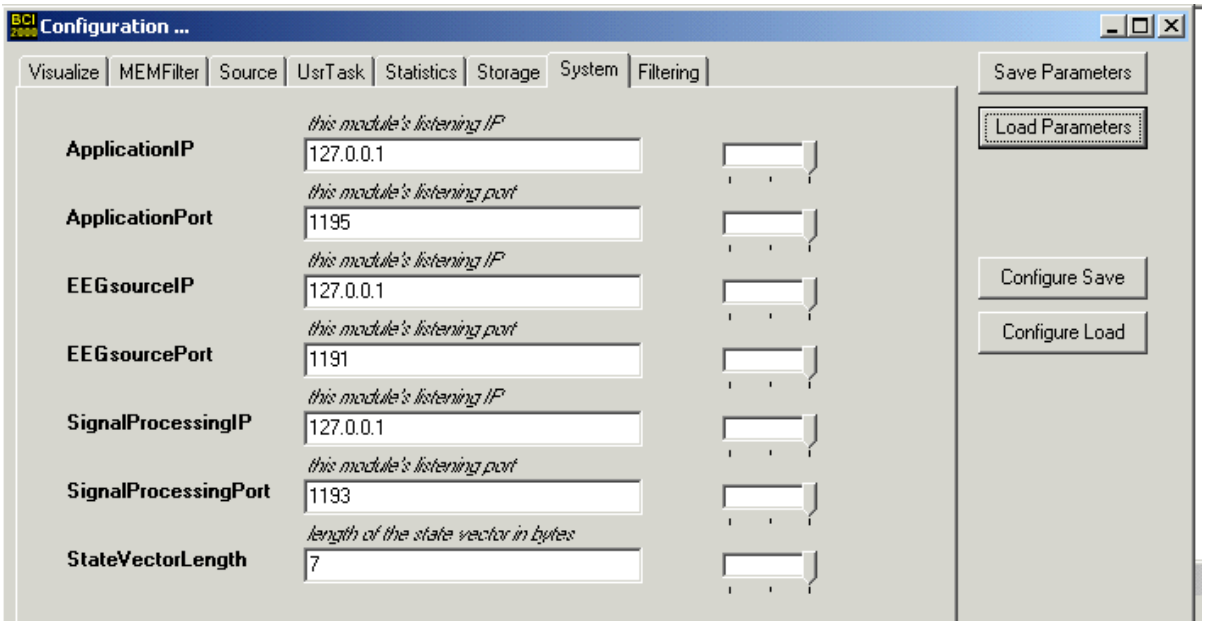
Figure 21. Appearance of the **Visualize** menu..

The **Visualize** menu has the following parameters:

SourceMax- maximum expected value of the source (raw data) display.
SourceMin- minimum expected value of the source display (these values scale the display).
VisualizeCalibration- whether or not the results of the calibration are shown.
VisualizeClassFiltering- whether or not the results of the classifier are shown
VisualizeNormalFiltering- whether or not the results of the normalizer are shown
VisualizeSource- whether or not the raw data are shown
VisualizeSpatialFiltering- whether or not the results of spatial filtering are shown.
VisualizeStatFiltering- whether or not the proportion correct by targets is shown
VisualizeTemporalFiltering- whether or not the results of the spectral analysis are shown

The **System** menu displays system configuration data and is shown in Figure 22. These values are not normally changed by the operator and should not be saved or loaded.

Figure 22. Appearance of the **System** menu.



These values can be omitted from saving and loading in the parameter file by clicking on these buttons on the right side of the screen as illustrated in Figure 23.

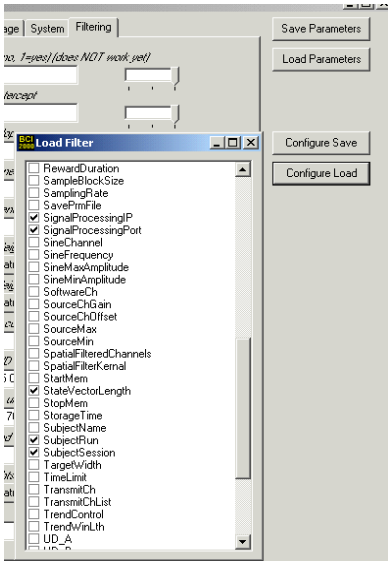


Figure 23. Appearance of the **Config Load** menu illustrating omission of system parameters.

Table 1.1. List of BCI2000 parameter interdependencies. Note that all parameters in the same group must match.

Parameter	Menu	Type	Group
TransmitCh	Source	numeric	A
SourceChGain	Filtering	number of elements in list	A
SourceChOffset	Filtering	number of elements in list	A
SpatialFilteringKernal	Filtering	matrix - number of columns	A
SpatialFilteringKernal	Filtering	matrix- number of rows	B
SpatialFilteringChannels	Filtering	numeric	B
MUD	Filtering	matrix- number of columns	B
MLR	Filtering	matrix- number of columns	B
StopMem-StartMem / membandwidth	MEMFilter	computed- number of spectral bins	C
MUD	Filtering	matrix- number of rows	C
MLR	Filtering	matrix- number of rows	C

Chapter 2- The screening program

As noted earlier, BCI2000 consists of four separate programs that run simulaneously. These are the operator, data acquisition, signal processing, and the user application. Different versions of these programs can be run with the BCI2000 system. One alternative user application is the screening program. This can be launched manually or with a batch file, as discussed in the beginning of chapter 1. In either case, the appearance of the various menus are similar with the exception of the **UsrTask** menu. When the screening program is run, the **UsrTask** menu appears as shown in Figure 2.1.

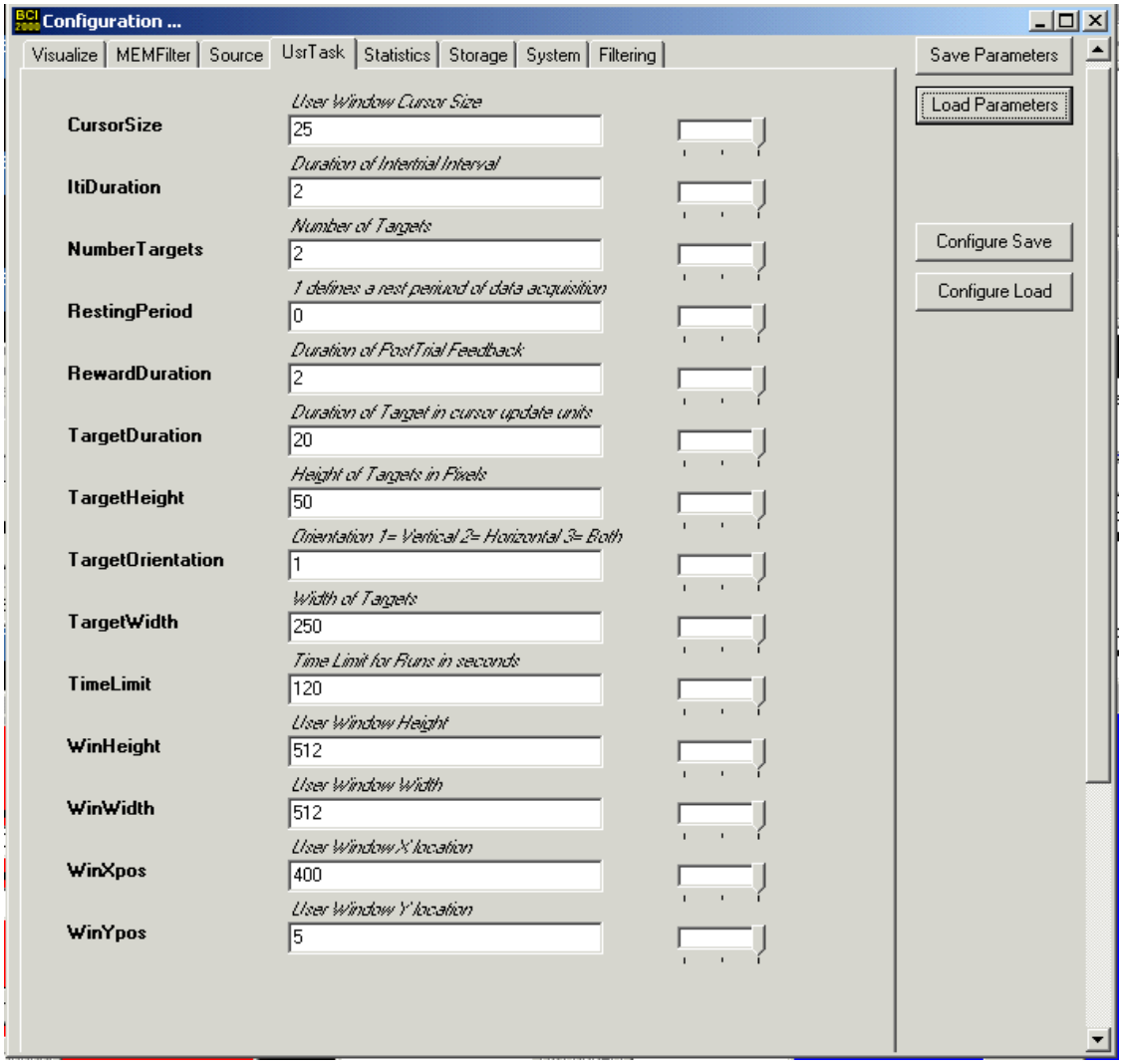


Figure 2.1. Appearance of the **UsrTask** menu when running the screening program.

Note that most of the parameters remain unchanged with the exception of the addition of **TargetOrientation** and **TargetDuration**. Also, parameters referring to the cursor are not present. The screening program has no cursor or cursor movement. Hence the duration of screening trials is determined by the **TargetDuration** parameter. In addition, the target appearance for the screening program is different. Figure 2.2 shows the user screen for the screening program.

Figure 2.2. Appearance of the user screen with the screening program.

Note that the target appears on the bottom of the screen. Whereas the initial user task had targets aligned along the right edge of the users' screen, the screen task has targets on the top and bottom edge of the Users'screen (for TargetOrientation = 1) or on the left and right edges of the Users'screen (for TargetOrientation= 2).

Chapter 3- The FIR program.

As we saw in chapter 2, different versions of the four separate programs comprising BCI2000 can be used interchangeably. An example of an alternative signal processing program is the **FIRProcessing** program. The use of digital filters (e.g. fixed-impulse, or FIR) is an allternative to AR-based spectral analysis. Most menus are identical with the FIRProcessing program. The exception is that the **MEMFilte**r menu is replaced with a **FIRFiltering** menu. The appearance of the FIRFiltering menu is shown in Figure 3.1.

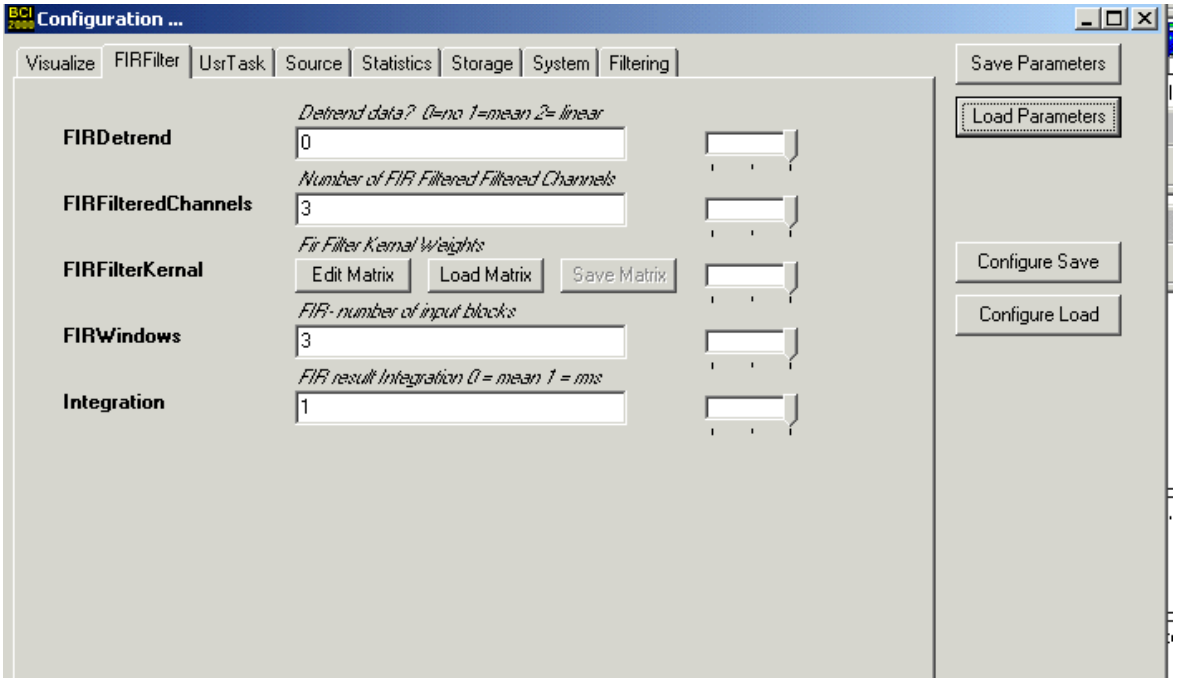


Figure 3.1. Appearance of the FIRFiltering menu.

The **FIRFiltering** menu has the following parameters:

FIRDetrend- determines whether or not linear detrending is performed.
FIRFilteredChannels- the number of channels that will be filtered
FIRFilterKernal- a matrix of the FIR filter weights.
FIRWindows- number of data blocks that are combined at each filtering cycle.
Intergation- determines whether the mean (0) or RMS (1) value is output.

During normal operation the **FIRFilterKernal** is loaded with the **Load Matrix** option. It can be produced by running the program **MakeFir**.

The **MakeFir** program produces a matrix output that can be read directly into BCI2000 with the Load Matrix option. The appearance of the **MakeFir** main window is shown in Figure 3.2.

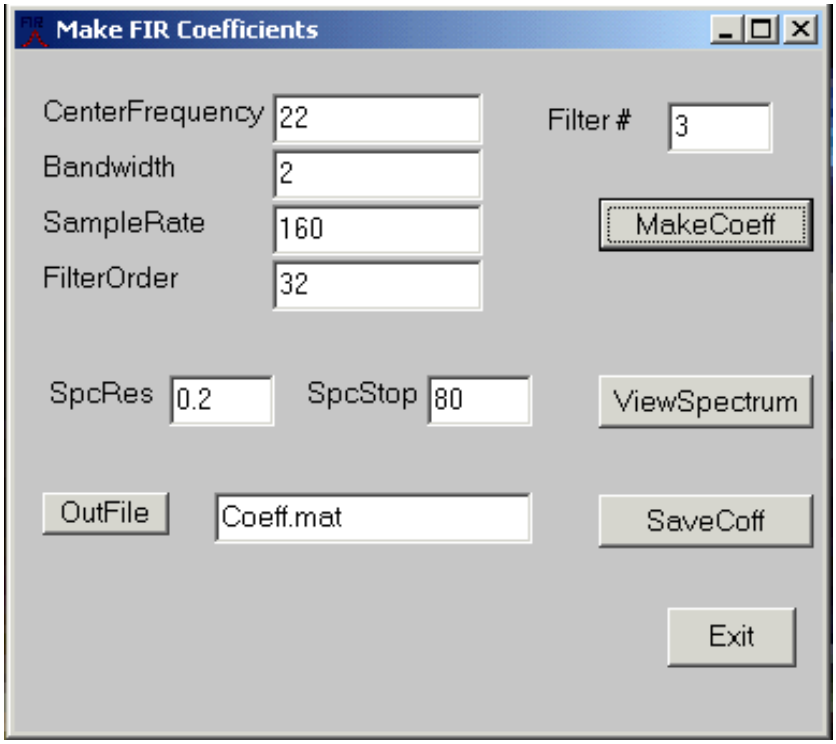


Figure 3.2. Appearance of the **MakeFir** menu.

The desired parameters are selected for each filter and then **MakeCoeff** is depressed. Each time MakeCoeff is depressed, filter coefficients determined by the current parameter settings are produced and the Filter # counter is advanced. Figure 3.3 shows the window displayed when **ViewSpectrum** is depressed.

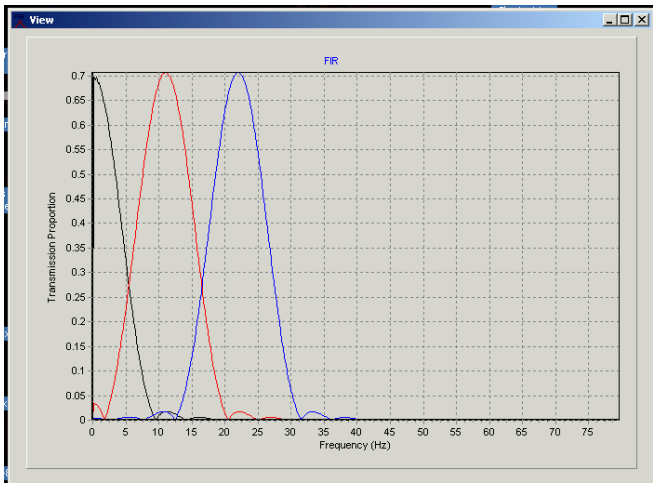


Figure 3.2. Appearance of the ViewSpectrum menu.

Figure 3.2 shows an example of the band-pass characteristics of three 32nd order filters centered at 0, 11 and 22 Hz. If the operator is satisfied with these characteristics a file name can be selected with the **OutFile** button and created by depressing the **SaveCoff** button. Note that the MakeFir menu has a Bandwidth option. The bandwidth will not be less than the value selected, but the width is also limited by the filter order.

Chapter 4- The Calibgen program

As noted in chapter 1, the BCI2000 **Source** menu has the parameter **TransmitCh** and the parameter list **TransmitChList** that specify which channels are sent from the EEG source program to signal processing. The **Filtering** menu has the parameter lists **SourceChGain** and **SourceChOffset** that provide information for calibration of these same channels. All of these parameters can be generated from the **Calibgen** program.

The **Calibgen** program takes as input a BCI2000 data file containing a calibration signal. The user selects the desired channels. The output is a BCI2000 parameter file fragment. The initial appearance of the **Calibgen** program is shown in Figure 4.1.

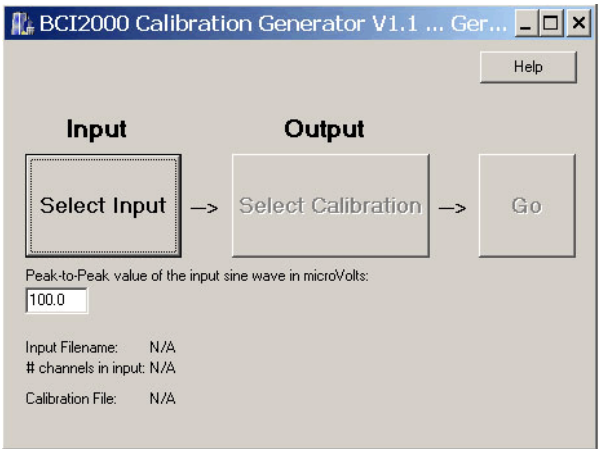


Figure 4.1 Appearance of the Calibgen main window.

Click on the SelectInput button and the next window appears as shown in Figure 4.2.

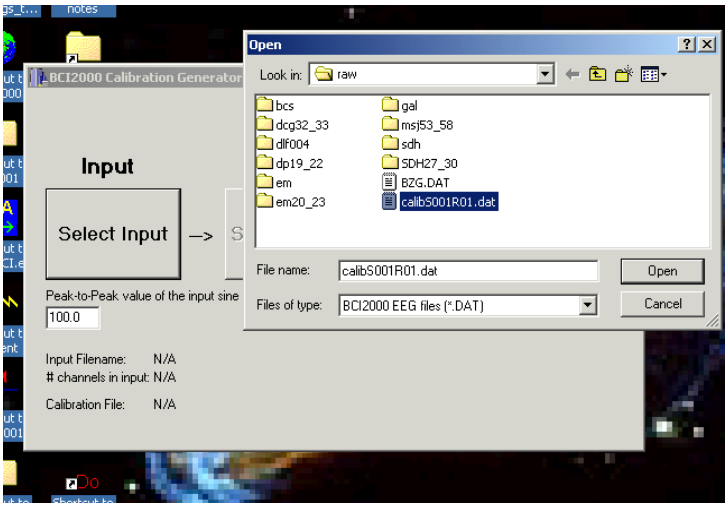


Figure 4.2. The Calibgen input window.

Next select the output file.

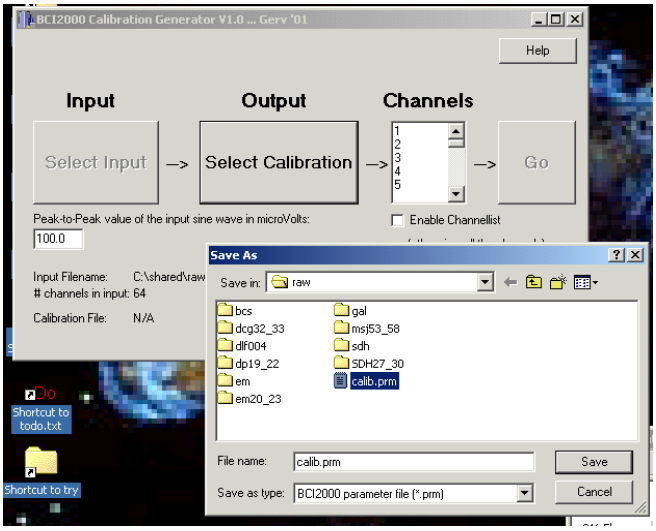


Figure 4.3. Appearance of the output window.

Then click on go. The selected file name will contain a BCI2000 parameter file fragment similar to that shown below:

Parameter File Fragment **Calib.prm** Generated by **Calibgen**

Filtering floatlist SourceChOffset= 5 245 -202 -86 -155 17 0 -500 500 // offset for channels in A/D units
Filtering floatlist SourceChGain= 5 0.00802 0.00806 0.00797 0.00805 0.00807 0.033 -500 500 // gain for each channel)

This file can now be read into BCI2000 with the **Load Parameters** option.

Chapter 5 - **BCI2000 file formats**

As noted in chapter 1, the storage menu allows for input of **FileInitials** and **SubjectName** as parameters. These parameters determine the location of the BCI2000 data files. FileInitials represents a file path where subdirectories associated with each **SubjectSession** are placed. For example, Figure 5.1 shows a file structure created by BCI2000.

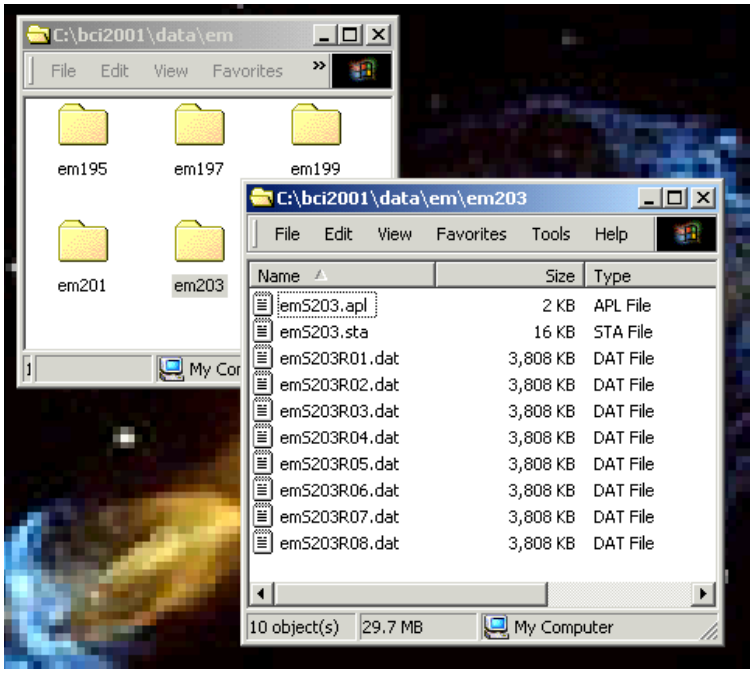


Figure 5.1- File structure associated with a complete BCI2000 session.

In the example shown, the value for **FileInitials** was **c:\bci2001\data\em**, the value for **SubjectInitials** was **em** and **SubjectSession** was advanced (automatically) from **1 to 8.** As can be seen in Figure 5.1, a separate *.dat file was created for each run. The complete description of the *.dat file format can be found in the **BCI2000 project outline**. Briefly, the *.dat file consists of an ASCII header (that can be viewed with standard programs such as notepad) that contains all system parameters and state definitions followed by the actual EEG data in binary format. Note that directories that do not exist are created automatically. Also new data files are created automatically at the beginning of each run using the next highest number. The program scans the directory to avoid overwriting any files.

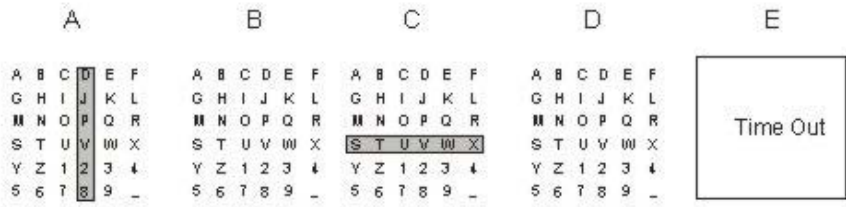
Two additional files are presently created. The *.apl file contains a brief summary of the subjects' performance as illustrated below:

```
        emS203.apl
Thu Sep 13 12:42:55 2001

Run  1   Hits= 30  Total= 32  Percent= 93.75
Number of Targets= 2
Bits=   21.21
Time Passed (sec)= 180.06
.....

Run  2   Hits= 26  Total= 32  Percent= 81.25
Number of Targets= 3
Bits=   22.44
Time Passed (sec)= 180.06
.....

Run  3   Hits= 24  Total= 32  Percent= 75.00
Number of Targets= 4
Bits=   25.36
Time Passed (sec)= 180.06
.....

Run  4   Hits= 27  Total= 32  Percent= 84.38
Number of Targets= 4
Bits=   36.07
Time Passed (sec)= 180.05
.....
```

This example is truncated at 4 runs for the sake of saving space. In addition, a *.sta file is created. This is the output of the **sta**tistics filter and provides trial-by-trial information concerning dynamic adaptation of BCI2000.

Chapter 6- The BCITimeFrequency Program

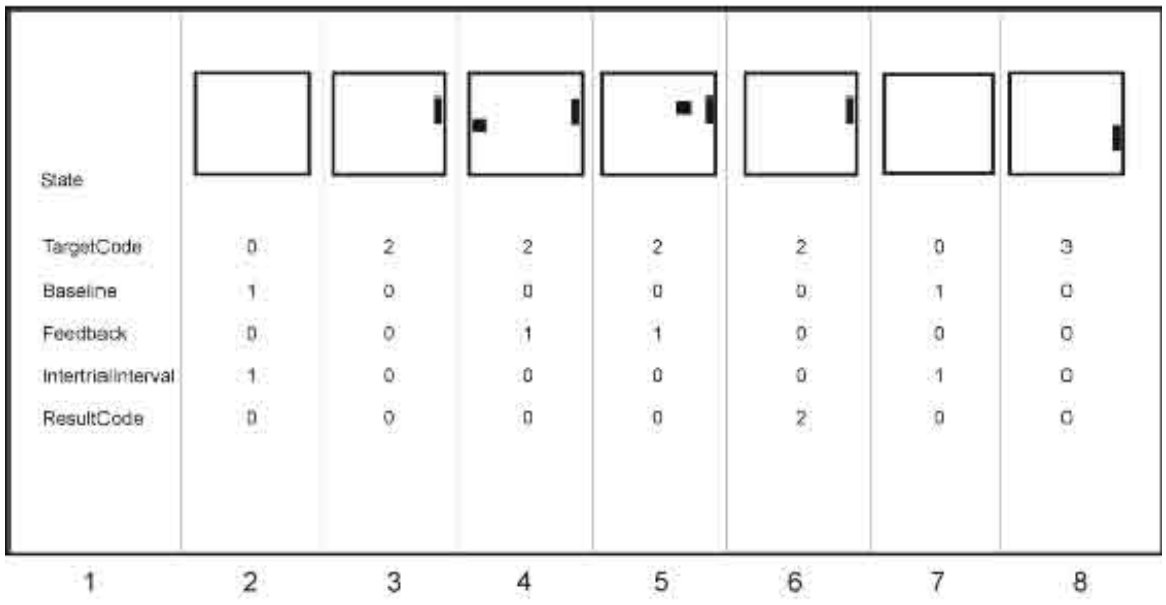
BCITimeFrequency extracts time-domain or frequency-domain data from BCI2000 Files and produces ASCII output files. It is based on the BCI state model. For the P300 Speller task this model is shown below:



StimulusCode	4	4	10	10	0
StimulusType	1	1	0	0	0
Flashing	1	0	1	0	0
SelectedTarget	0	0	0	0	16

There are 4 state variables illustrated here. StimulusCode refers to the currently active row/column number. StimulusType refers to whether the current row/column is a target or standard. Flashing refers to whether or not the current stimulus is intensified. Finally, SelectedTarget refers to the row/column combination that is selected at the end of one complete scan sequence. In the example above, the letter P is the target (values of stimulus code being 4 (for row #) and 9 (for column #). The example illustrates a successful selection (SelectedTarget being 16).

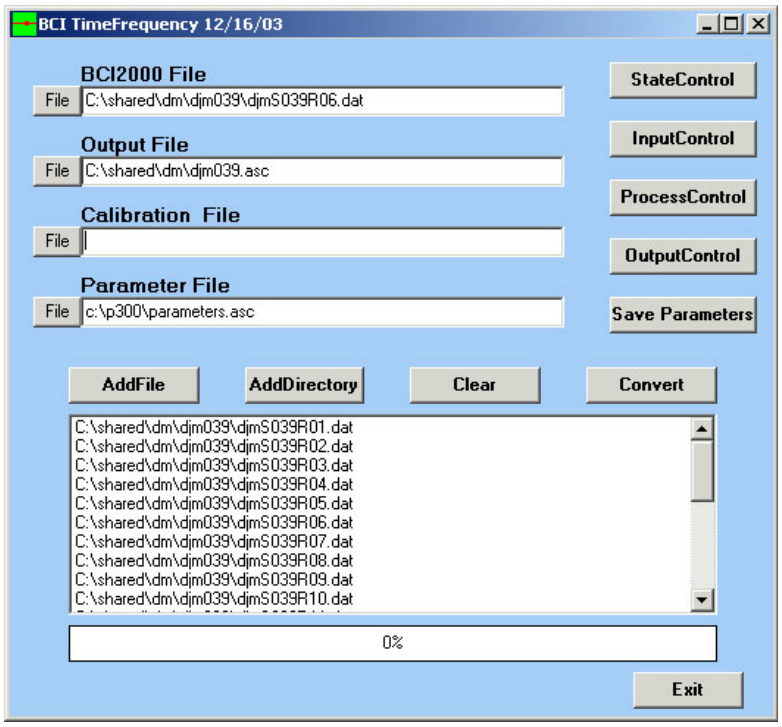
The state model for the RJB task is illustrated below:


State
TargetCode 0 2 2 2 2 0 3
Baseline 1 0 0 0 0 1 0
Feedback 0 0 1 1 0 0 0
IntertrialInterval 1 0 0 0 0 1 0
ResultCode 0 0 0 0 2 0 0
1 2 3 4 5 6 7 8

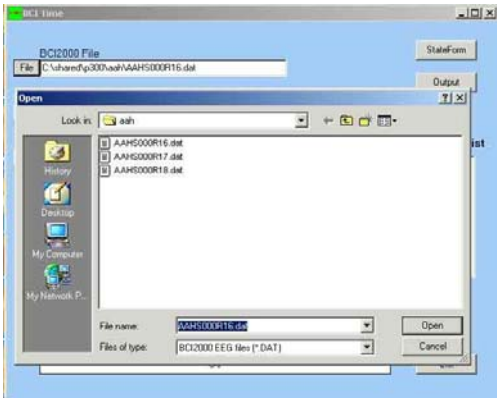
Four target rjb task. 1 is the intertrial interval were the screen is blank and baseline data can be collected (optional). In 2 the target is presented but the cursor is absent (no feedback). In 3 the cursor is present and it's vertical movement is controled by the user's EEG. Horizontal cursor movement is under computer control and is at a constant rate. In 4 the cursor approaches a the target and in 5 the target has been hit and trial-outcome feedback is presented. In 6 the screen is blank (intertrial interval again) and in 7 another target is presented.

Note that control of the state of the user screen depends upon the values of several state codes. In the present 4-target example, TargetCode specifies which of the 4 targets is currently present. When it is 0, no targets are present. Feedback specifies the presence of the cursor. Normally we are interested in analyzing data associated with specific targets when the cursor is present.

The BCI time main menu appears below:



This menu contains 4 controls for entering files, several buttons for process control, and a Memo box for channel selection. If the File button for BCI File is selected the following dialog box appears:

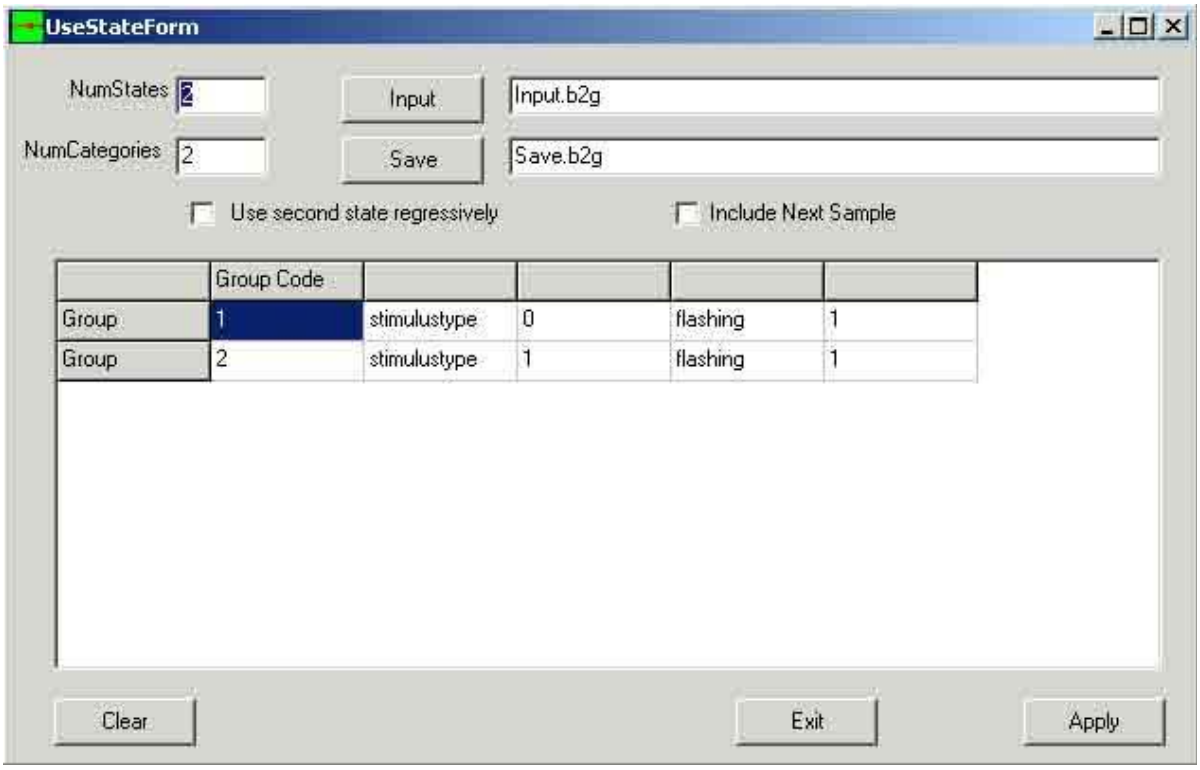


This allows selection of the input directory.

The lower memo box has buttons for “add file” and “add directory”. These are used for adding either the individual file or all bci data files contained in the current directory. The list can be added to considerably so that files from several directories can be concatenated.

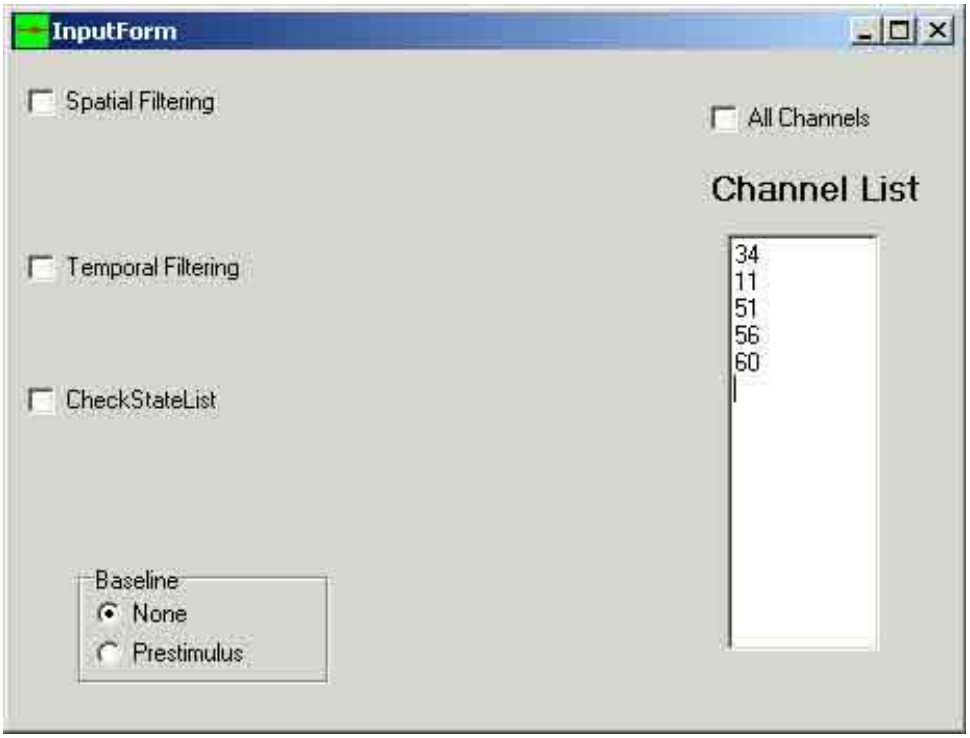
The OutputFile field is for the name of the ascii output file and the Calibration parameter file is for the calibration file for all channels generated by the Calibgen program.

If the stateForm button on the main menu is clicked (upper right) the following dialog box appears:



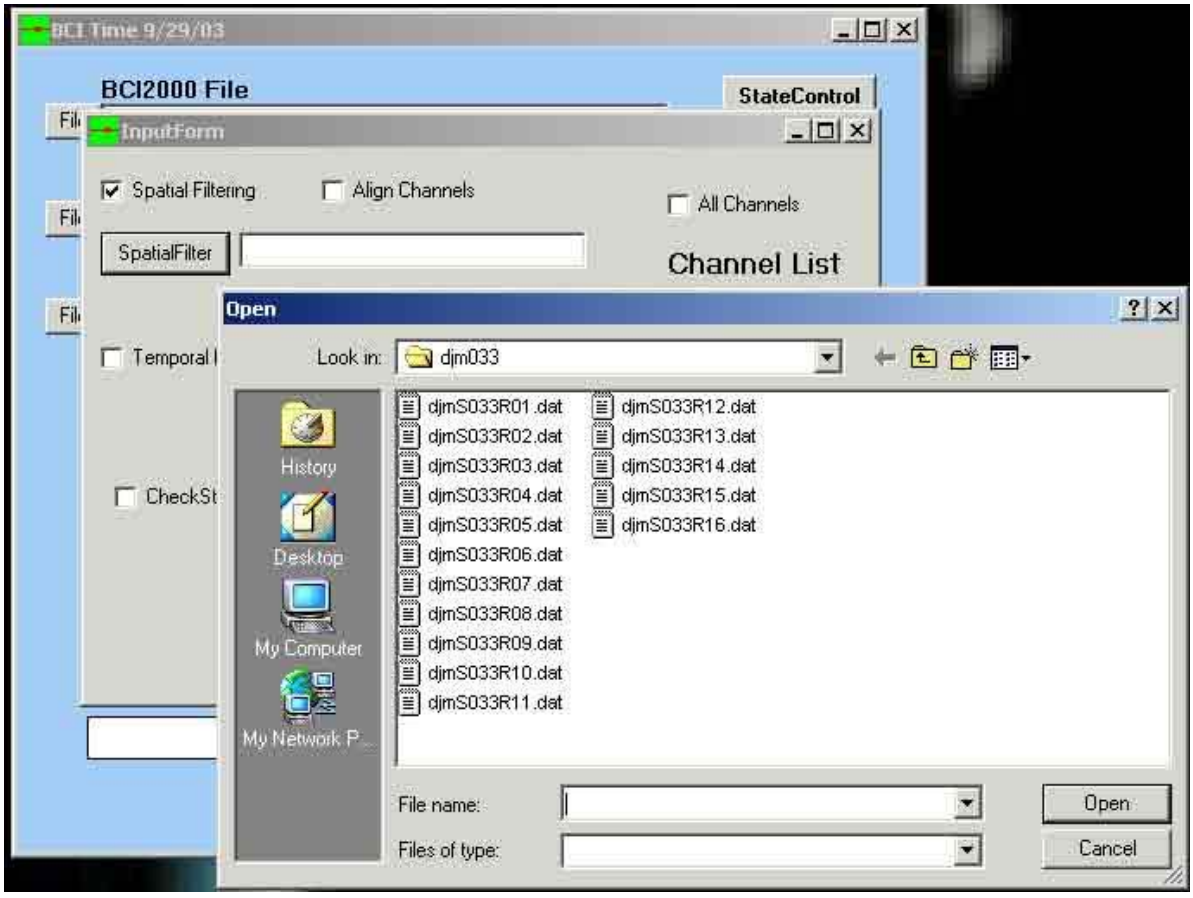
Entries here are based on the BCI state model shown in the beginning. The values shown appear as the default. They show two states (1 and 2) defined as the conjunction of statecode being 1 or 2 and flashing being 1. These groups will then correspond to target and standards. Other configurations could be entered manually or input/saved with the file buttons. The checkbox “Use 2nd State Regressively” causes the 2nd state value in the list to apply at the start of the 1st state value in the list. This is useful for situations where the two do not entirely overlap. The checkbox “Include Next Sample” causes the 1st sample following the selected state values to be included in the output. This is useful when one wants to use some outcome value.

The InputControl button on the main form produces the InputForm shown below.

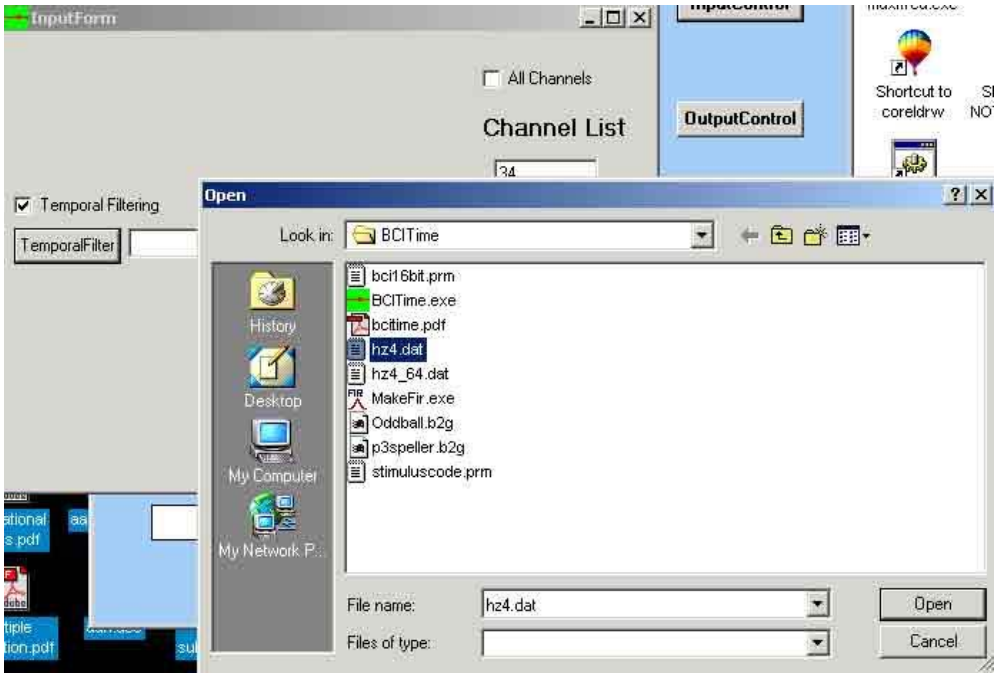


This allows for selection of a list of channels. If the “All Channels” box is checked the Channel List box will be filled with 64 entries. If this box is then unchecked the list is cleared.

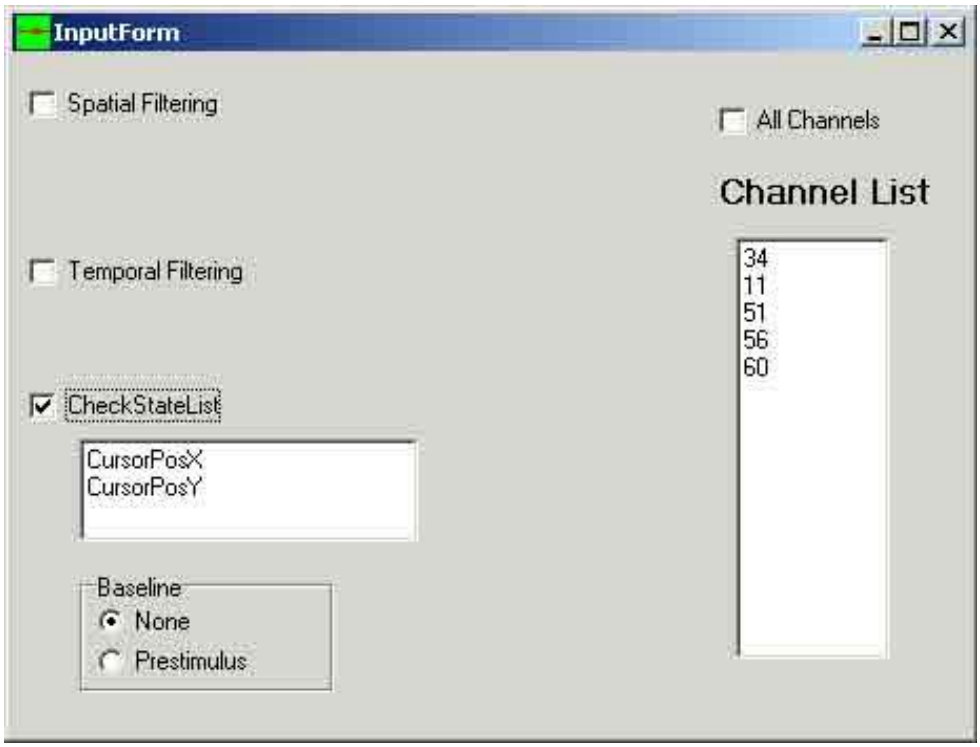
If the Spatial Filtering box is checked a button appears to allow selection of a spatial filter file. This file follows the format of spatial filter files saved by WinLaps.exe.



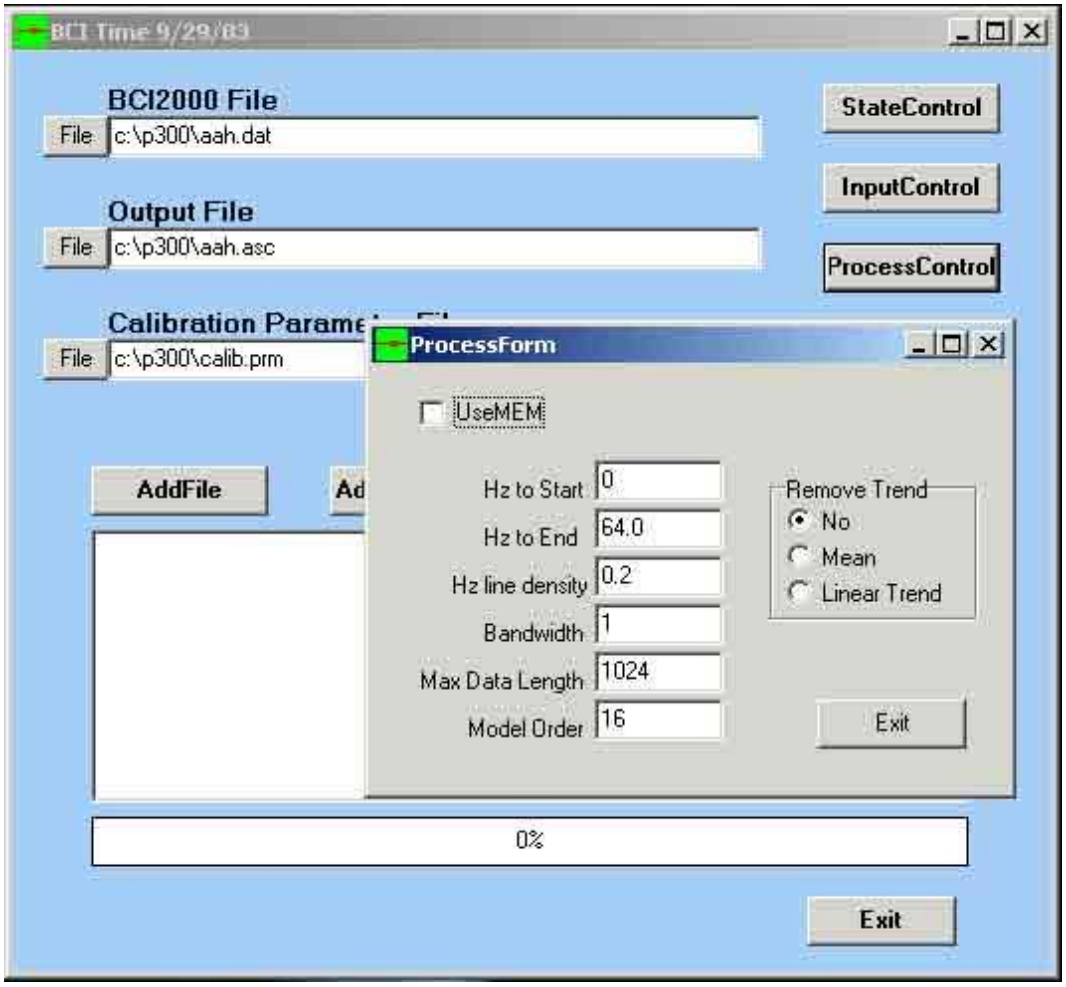
If the Temporal Filtering box is checked an input dialog box appears for inclusion of a file of FIR filter coefficients. This file can be produced by the “MakeFir.exe” program.



If the CheckStateList box is checked a dialog box appears that allows entry of state names. Values of the entered states will appear in the output in addition to EEG values.

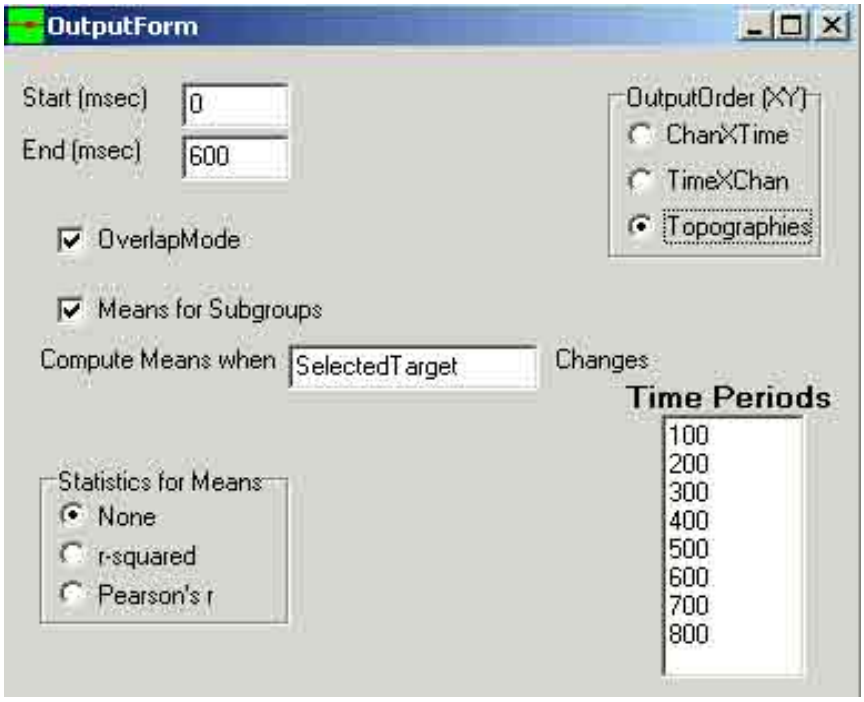


If the ProcessControl button is selected the ProcessForm menu appears that allows entry of parameters for spectral analysis.



If the "UseMEM" box is checked the output will be in terms of the square root of power in spectral bins as determined with the Burg algorithm.

The main form also has an Output button which displays the following dialog box:



In the example, the waveform will start at the beginning of the state code and end 600 msec after the initial onset. Overlapmode is selected. This indicates that values specified above should be retained even if the state values that define grouping are not immediatly present. The box "Compute means when" contains the state name "SelectedTarget". This indicated that means will be computed every time SelectedTarget changes value. Since this happens at the end of a complete series of scans it will produce means for each target letter

The box at the lower left allows for selection of statistics that compare the groups defined in the UseStateForm.

Finaly the checkbox "OutputOrder (XY) has "Topographiesl" selected. This refers to the orientation of the output matrix. This causes the "Time Periods" memo box to appear. Time values for HzPlot compatable topographies are entered here.

If the OutputOrder (XY) selection is TimeXChan an output like that shown below (except that

the range of time is truncated to allow a single line to fit on a page):

0	1	1	-1.514	-1.237	-1.386	-1.387	-1.207	-1.019	-1.018
0	1	2	-4.854	-4.458	-4.338	-4.285	-4.311	-4.169	-4.115
0	1	3	-4.448	-3.983	-3.621	-3.517	-3.643	-3.641	-3.632
0	2	1	4.610	4.734	4.799	4.795	4.820	3.988	2.565
0	2	2	2.642	2.980	3.142	3.010	2.941	2.103	0.640
0	2	3	4.386	4.742	4.763	4.338	4.098	3.338	2.114
0	1	1	0.513	0.416	0.249	-0.058	-0.291	-0.102	0.216
0	1	2	-1.326	-1.525	-1.668	-1.780	-1.881	-1.696	-1.478
0	1	3	-2.587	-2.496	-2.369	-2.331	-2.461	-2.448	-2.415
0	2	1	3.832	2.970	2.663	3.397	4.241	3.517	2.406
0	2	2	2.079	1.453	1.327	1.996	2.456	1.536	0.657
0	2	3	3.439	3.020	2.898	3.261	3.411	2.451	1.760
0	1	1	0.609	0.036	-0.245	-0.004	-0.064	-0.267	0.175
0	1	2	-1.836	-2.350	-2.566	-2.308	-2.390	-2.678	-2.527
0	1	3	-2.207	-2.293	-2.264	-2.190	-2.359	-2.476	-2.438
0	2	1	3.450	2.738	3.052	4.043	4.643	4.107	3.570
0	2	2	2.090	1.678	2.110	2.937	3.201	2.498	2.116
0	2	3	3.601	3.390	3.724	4.234	4.241	3.453	3.096

The first column contains the value of “SelectedTarget” (or whatever was entered into “Compute means when...”) just prior to when it changed. The second column contains the grouping variable and the third column contains the channel number (numbered consecutively from the list in the main menu). The successive values of the mean waveform follow.

Other configurations can produce different outputs. For example, if “Compute means when ...” contains the statename “StimulusCode” separate values will be produced for each row or column intensification and the output will appear as below:

9	1	1	-11.586	-14.158	-13.987	-10.814	-10.042	-10.256	-10.685
9	1	2	-26.773	-28.784	-27.501	-23.865	-23.565	-23.694	-22.710
9	1	3	-20.919	-22.379	-20.232	-16.454	-16.583	-16.626	-15.553
9	2	1	-0.651	0.507	-4.639	-6.569	-5.797	-4.639	-2.581
9	2	2	-14.925	-13.385	-18.262	-19.801	-19.930	-19.801	-18.518
9	2	3	-3.317	-1.127	-4.991	-6.537	-6.537	-7.696	-7.696
5	1	1	-5.797	-3.481	-2.581	-4.125	-5.025	-5.925	-6.826
5	1	2	-24.036	-22.753	-22.368	-22.239	-20.571	-21.598	-24.549
5	1	3	-19.030	-20.028	-18.418	-15.359	-14.715	-14.812	-14.812

Here the first column is the specific row/column, the second is the group code (target/standard) and the third column represents the channel number. Likewise, if “Compute means when” is blank then an overall mean will be generated for all data in all files included in the run.

The StateForm menu can also be used to vary the output.

Chapter 7 - The P300 Speller

Use of the programs P3Signalprocessing.exe and P3Speller.exe in conjunction with data acquisition and operator modules allows for use of the P300 Speller. This configuration has the Visualize, Source, Statistics, Storage, System and Filtering menus as discussed earlier. In addition, the P300 configuration also includes the P3SignalProcessing and P3Speller menus.

The appearance of the P300 user screen is shown in Figure 6.1

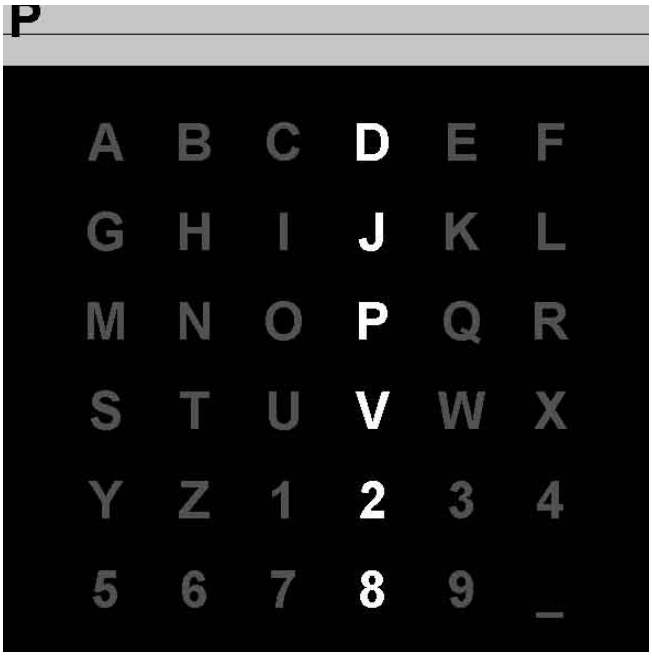


Figure 6.1 - The P300 User screen. Each of the 6 rows and columns are flashed (highlighted) in a block-randomized order. When N blocks have been completed a letter is selected.

The P3SignalProcessing menu is illustrated in Figure 6.2

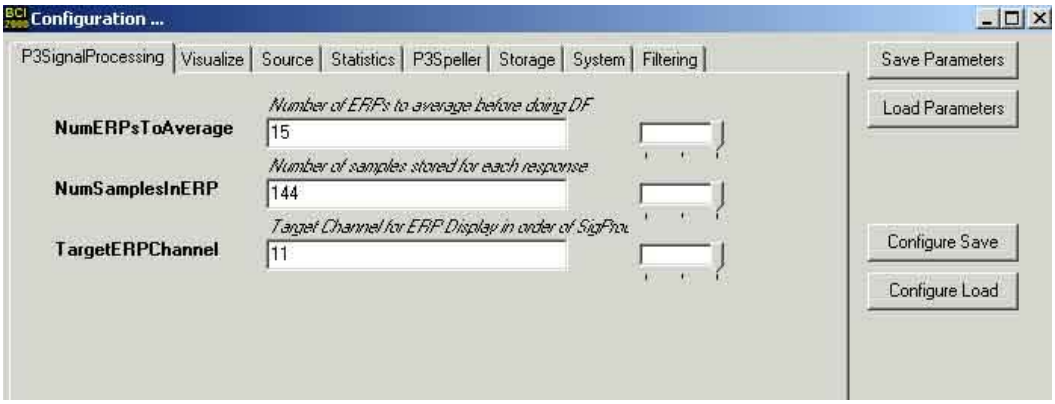


Figure 6.2 - The P3SignalProcessing menu. This menu allows 3 parameters to be entered:

NumERPsToAverage- the number of blocks to be averaged prior to classification.
NumSamplesInERP- the length of the ERP waveform in samples.
TargetERPChannel- the channel that is displayed in the VisualizeP3TemporalFilter window.

The P3Speller Menu is illustrated in Figure 6.3

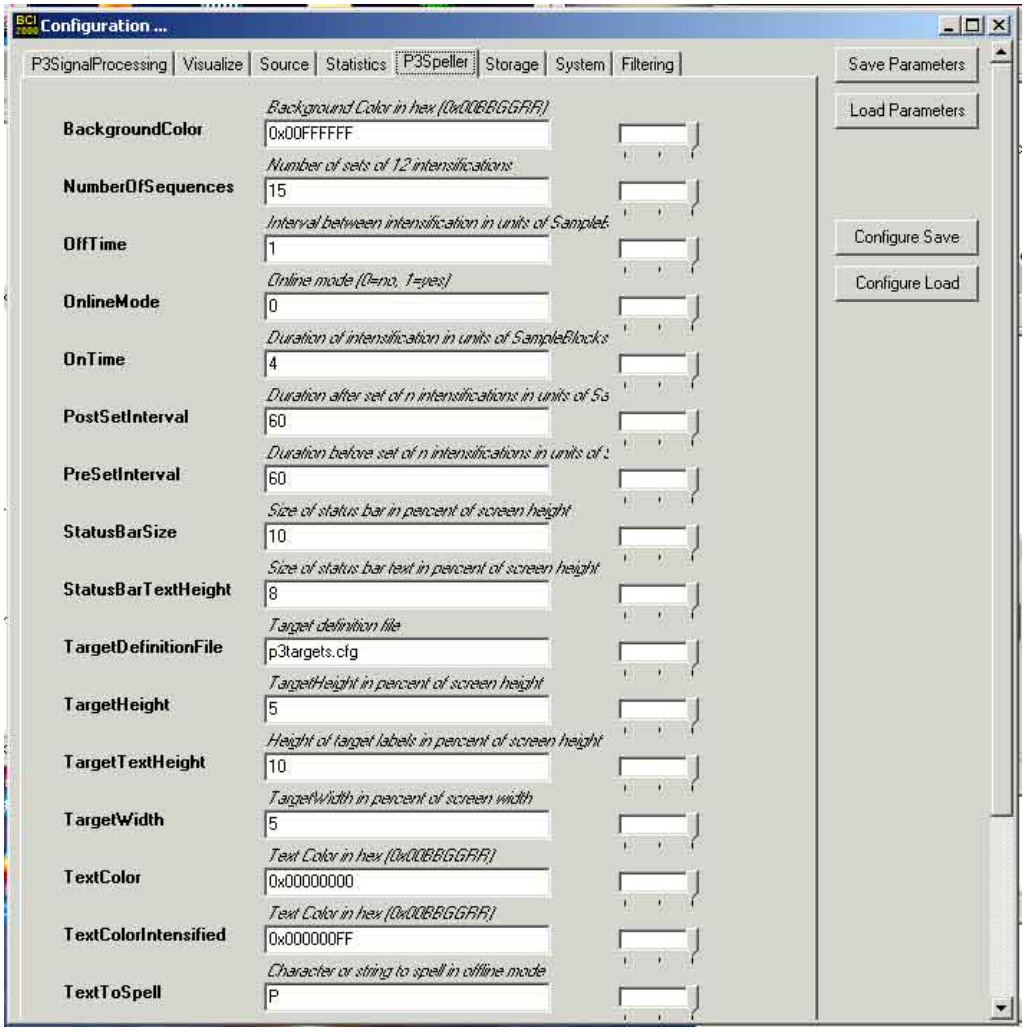


Figure 6.3 The P3Speller menu allows for entry of:

BackgroundColor - Hex values for the background of the User's screen. All 0s is black. In positions 3-4 more Blue is added as the value increases. The value in 5-6 adds green and the value in 7-8 adds red.

NumberOfSequences - The number of presentations per classification. Currently this must be an integer multiple of the value of NumERPsToAverage in the P3SignalProcessing menu.

OffTime - number of system cycles that the highlight is off.

OnlineMode - free spelling

OnTime - number of system cycles that the highlight is on

PostSetInterval- delay at end of set
PreSetInterval- delay at beginning of set
StatusBarSize- size of bar at top of user screen showing letters to spell and letters spelled
StatusBarTextHeight- size of text in bar at top of screen
TargetDefinitionFile- full path of file that defines selections on the screen
TargetHeight- height of area in which each letter appears
TargetTextHeight- height of the text in the target area
TargetWidth- width of area in which each letter appears
TextColor- hex bit pattern (BGR) that defines color of targets
TextColorIntensified- hex bit pattern that defines change when row/columns flash
TextToSpell- word(s) that subject must spell

Additional considerations:

Certain other parameters, covered in previous chapters, must be dealt with.

in the Filtering menu, values for MUD must be set to allow for classification of the P300. This works as covered previously except that the column 2 values are time points rather than frequency bins. For example, Figure 6.4 shows one configuration.

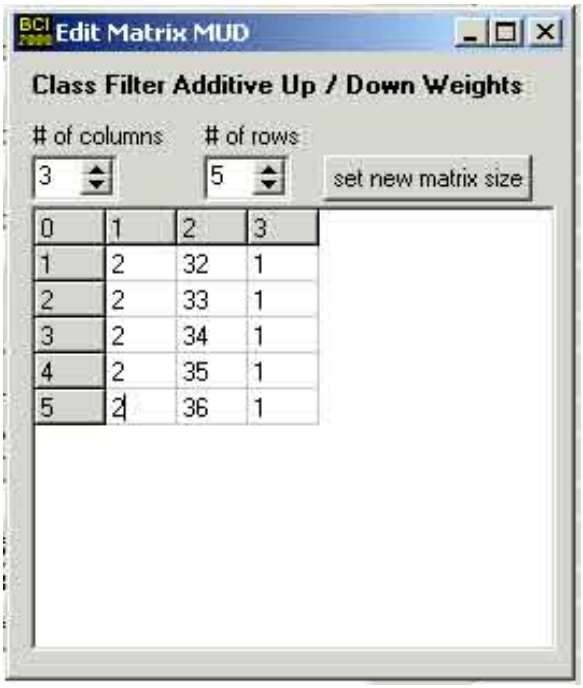


Figure 6.4 One possible configuration of MUD (from Filtering menu).

In this configuration, the values in column 1 indicate that signal 2 is being used for P300 classification. The values in column 2 indicate that time points 32-36 are used for classification. Finally, the values in column 3 indicate that all points are given equal weights (1).

Also, in the Filtering menu, the values of UD_A should be 0 and UD_B should be 10.

Chapter 7. Maxifred.exe

Maxifred.exe is a utility that can be used for visual inspection of BCI2000 data files. It provides for a simple “polygraph” type view of short segments of data. Upon clicking on the programs icon the following form appears.

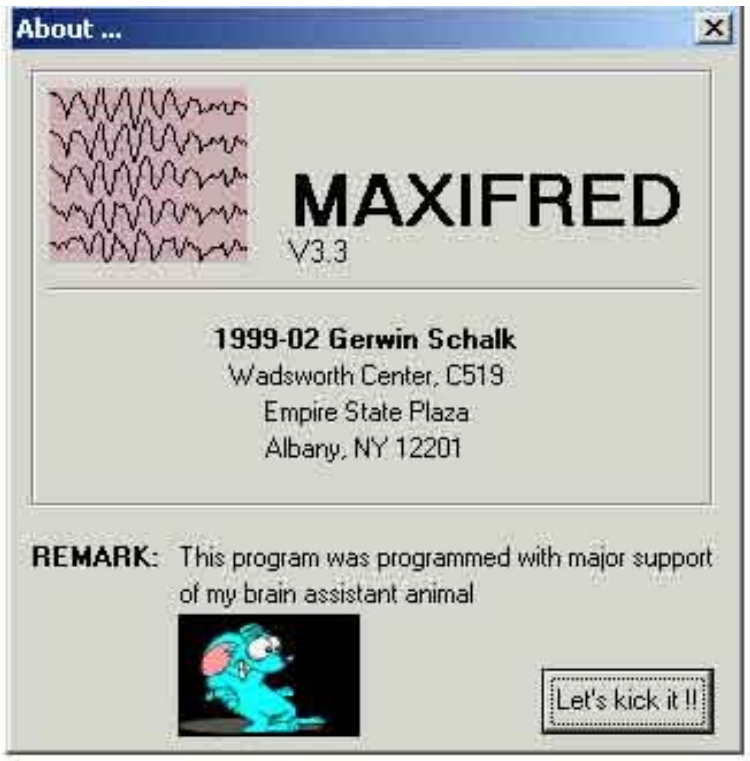


Figure 7.1- The initial Maxifred form.

Click on “Let’s kick it!!” and proceed to the main form.

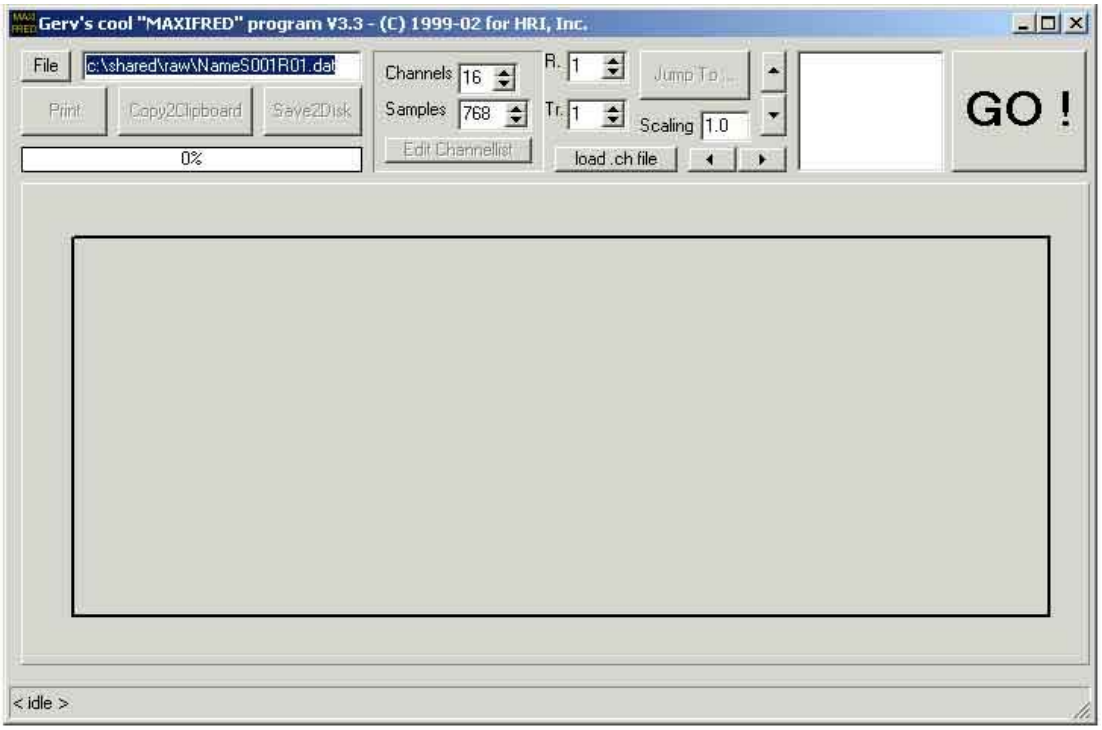


Figure 7.2. The main Maxifred. Click on the "File" button in the upper left hand of the form and the open file dialog appears.

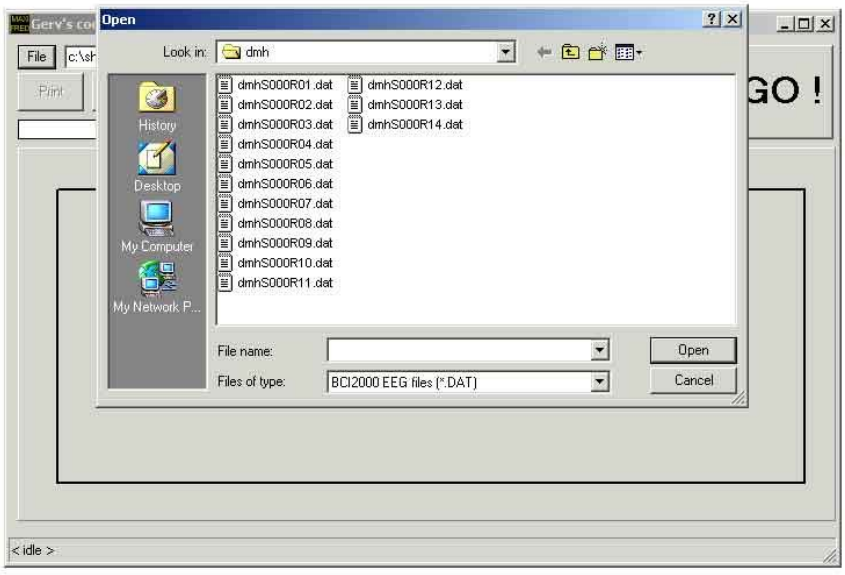


Figure 7.3. The open file dialog. Select the BCI2000 data file to view. When the main form appears select "GO" on the upper right of the form

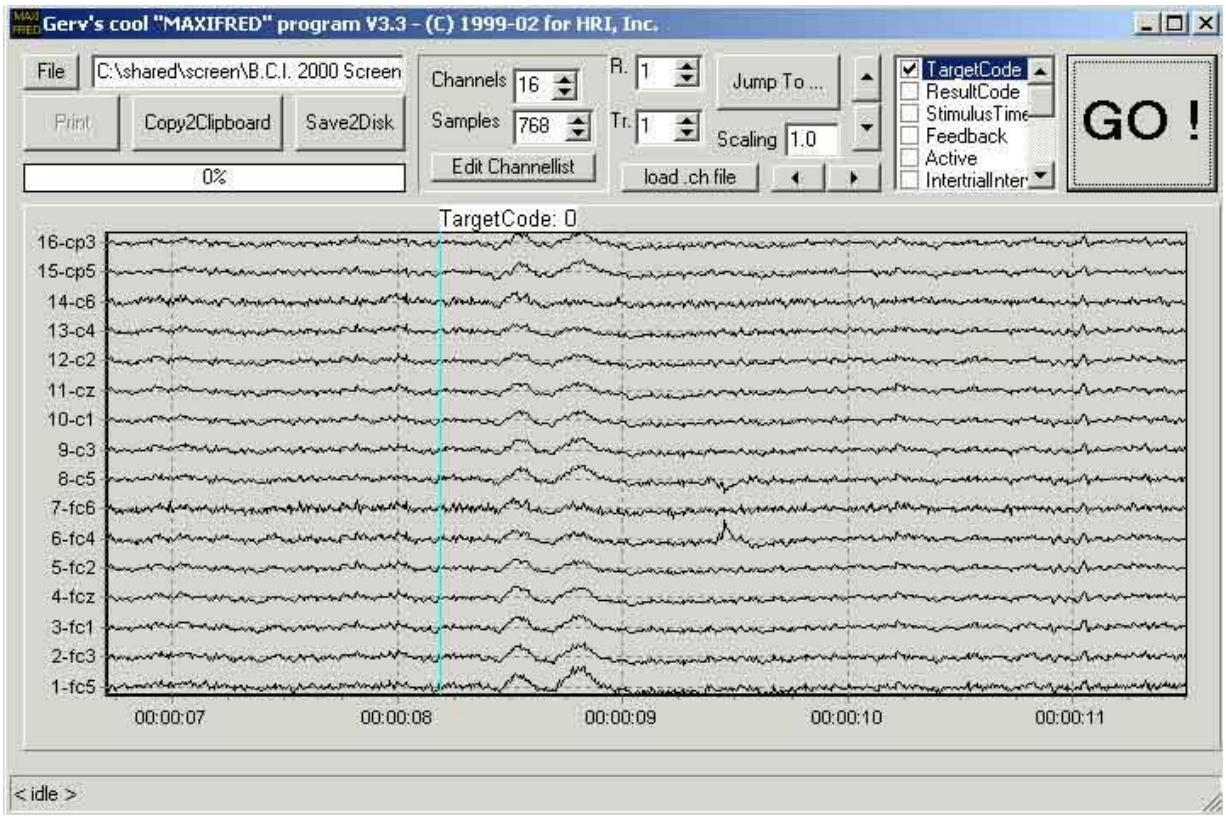


Figure 7.4. Display of BCI2000 data. Note the controls at the top of the form. The number of channels and points to display can be selected. The "Jump To.." button alows the user to advance to a selected trial within the BCI2000 run. Scaling controls the Y-axis amplitude of the EEG signals. There are also arrow buttons that control movement through the record. To the immediate left of the "GO" button is a list of State codes. This list is read from the data file and its contents will vary. Note that in the example "TargetCode" has been checked. This causes any change in the value of the state "TargetCode" to be marked on the record. Also note that the time within the run appears on the bottom of the record.

Figure 7.5 Magnification of some of the controls from Maxifred. Note the "Edit Channellist" button. If this is selected the form in 7.6 appears.

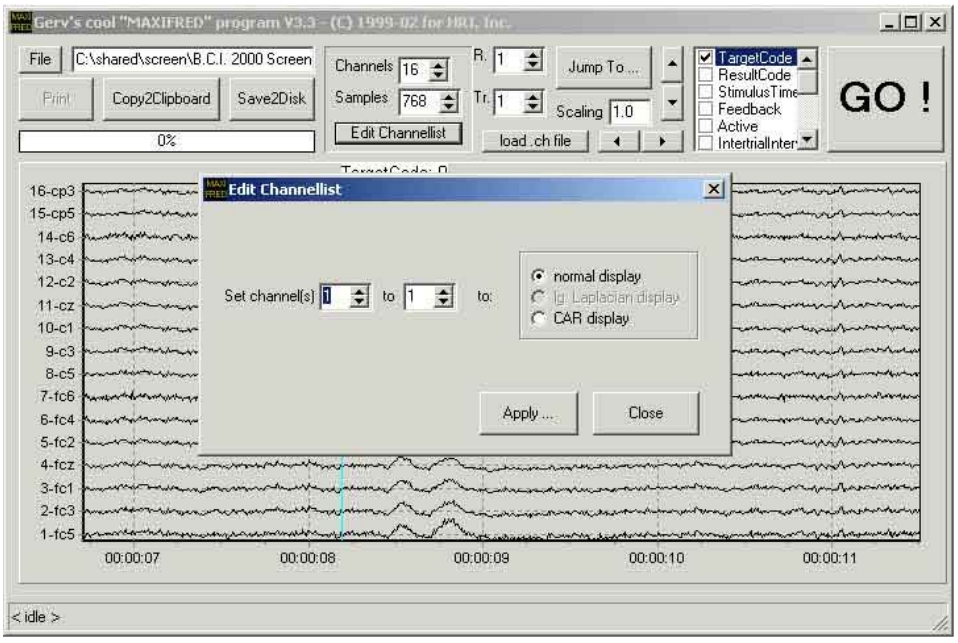


Figure 7.6. The Edit Channellist form. This menu allows application of the **C**ommon **A**verage **R**eference (CAR) to the displayed data.

EEG Samples from Maxifred.

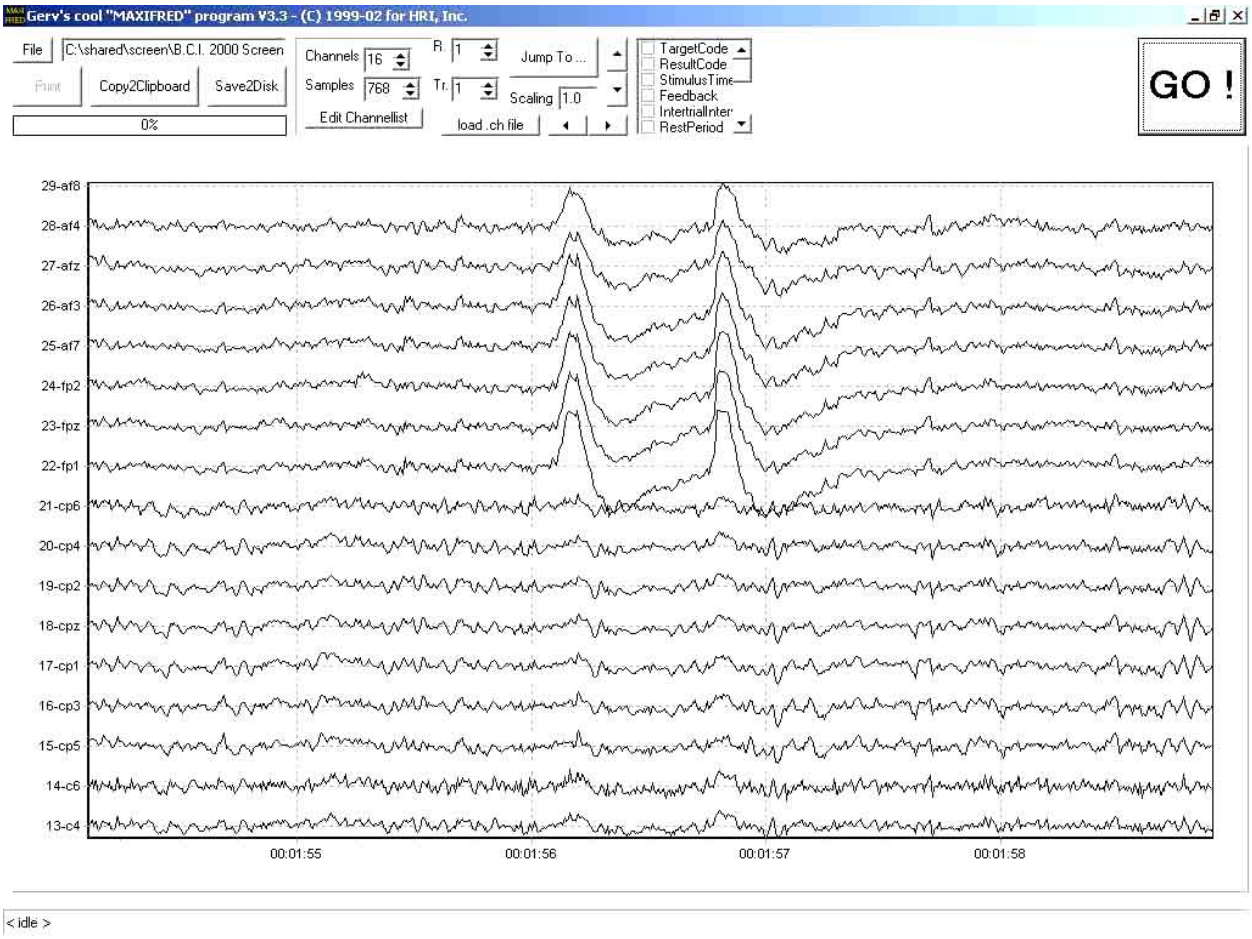


Figure 7.7 - EEG Sample that illustrates a pair of eye blinks that are apparent on channels fp1-af4 (22-28). Note that the eyeblinks affect all channels to some extent but are most pronounced in the front of the head (near the eyes).

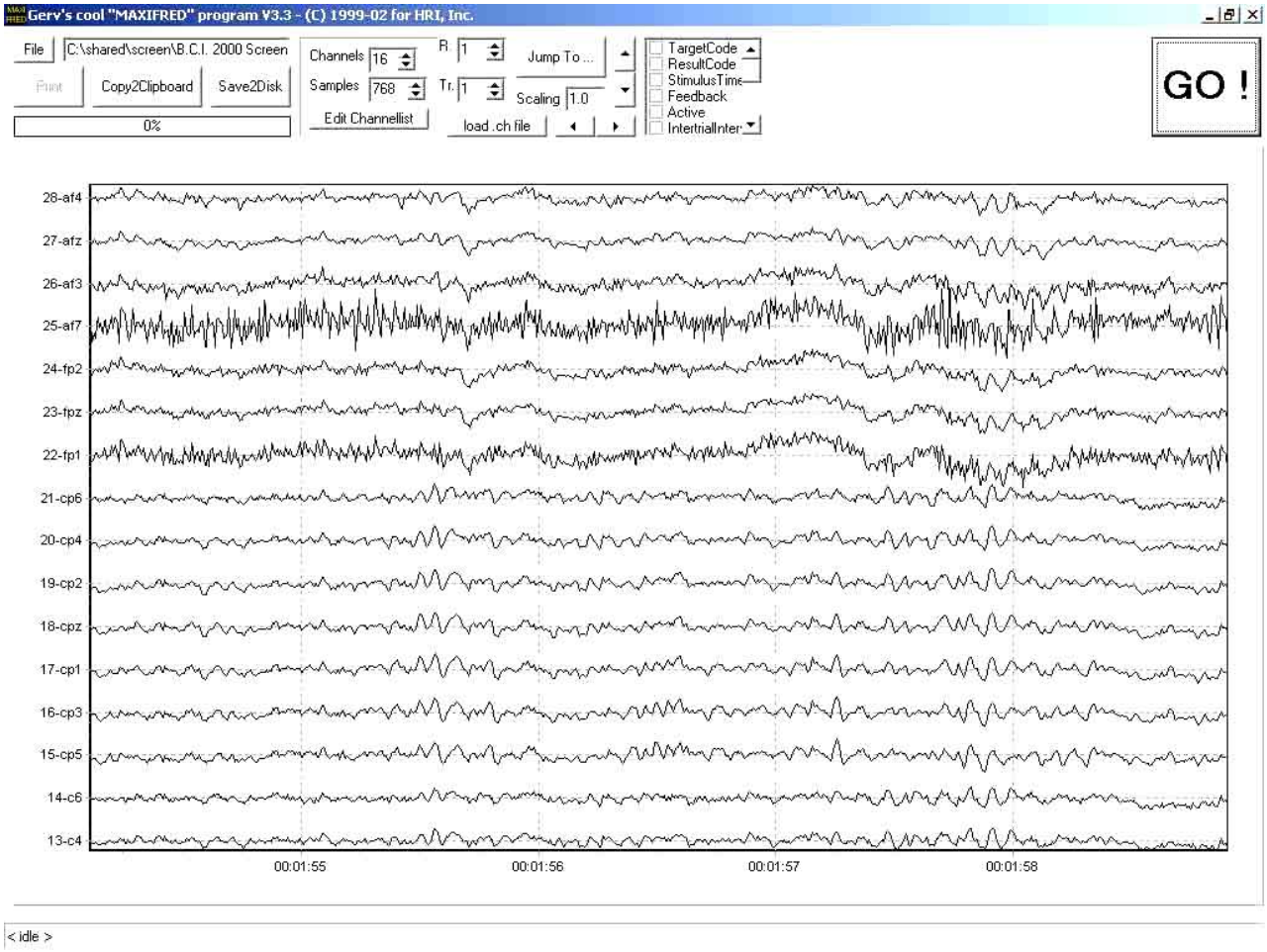


Figure 7.8 -. EMG activity that is particularly pronounced on channels af7 and fp1 (25 and 22). Also note the alpha-band spindles present throughout many channels (see Figure 3)..

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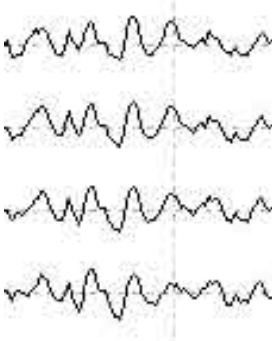
Figure 7.9 - Alpha spindles  from Figure 2.

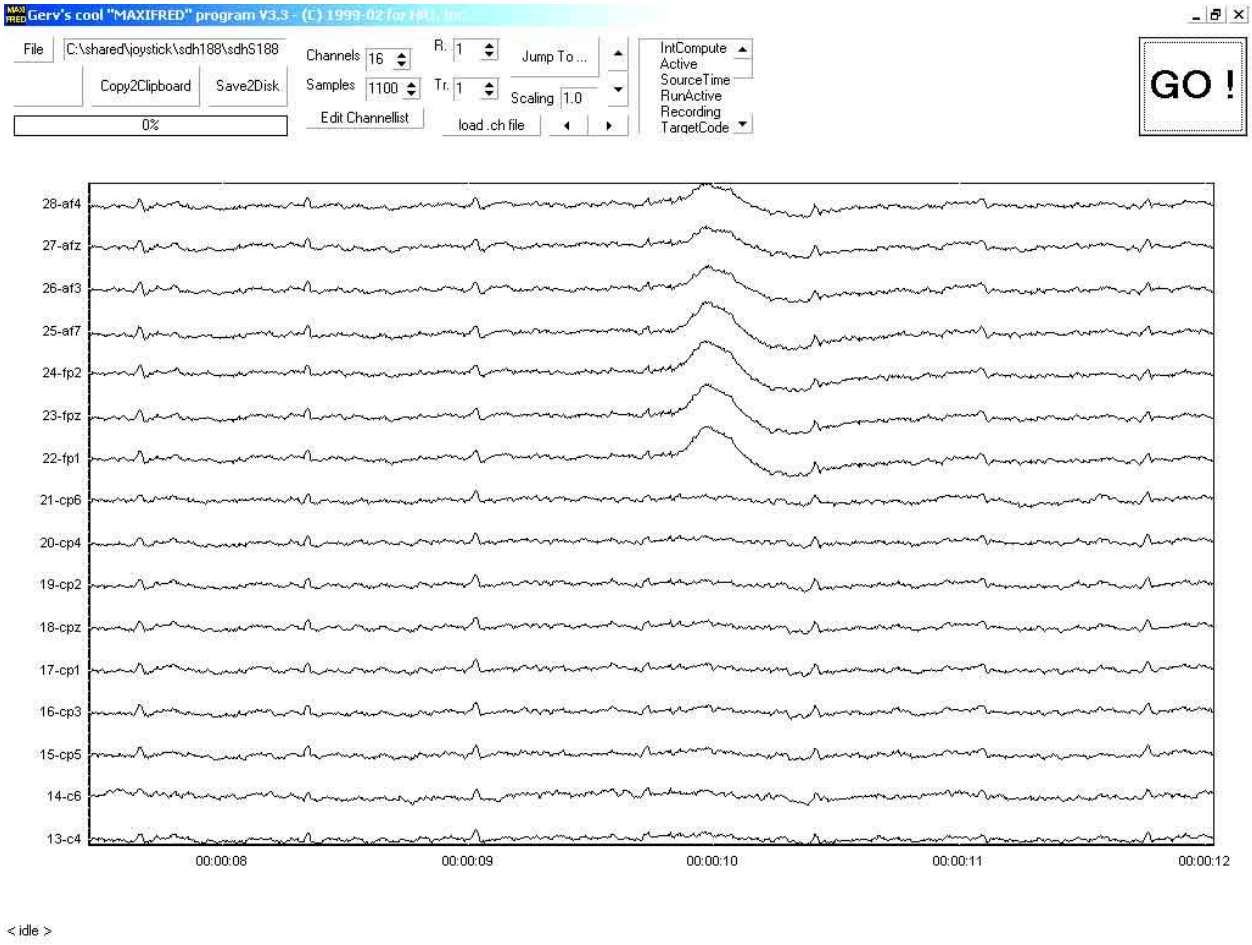


Figure 7.10 - EEG sample showing a large EKG effect. Note the regularly occurring, small upward deflection2 on all channels. There is also a single eyeblink.